DEVELOPMENT OF A TESTBED FOR LABORATORY VALIDATION OF NAVIGATION, ESTIMATION, AND SENSING ALGORITHMS

A Thesis

by

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ABSTRACT

A new robotic platform - the Navigation, Estimation, and Sensing Testbed (NEST) - was developed to support laboratory testing and validation of new guidance, navigation, and control (GN&C) and data fusion algorithms at Texas A&M University's Land, Air, and Space Robotics Laboratory (LASR). NEST combines a suite of environmental and inertial sensors, onboard computer, battery, and supporting power electronics into a compact, generic platform. Additionally, software was developed to provide data acquisition, storage, and transmission functionality. NEST serves as a vehicle emulation and sensing platform to facilitate hardware-in-the-loop (HIL) simulations in the laboratory, and can be operated stand-alone or as part of a larger network of machines. NEST's suite of sensors is presented, along with technical details and design methodology relating to NEST's electrical, mechanical, and software infrastructure. The thesis concludes with a discussion on the typical utilization of NEST in the laboratory setting and a brief summary of planned future work on the NEST platform.

DEDICATION

I dedicate this work to my God with gratitude for His provision and faithfulness, and to my wife Rebecca for her support and patience throughout the writing process.

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NOMENCLATURE

API	Application Programming Interface
AWG	American Wire Gauge
CGT	Camera Gantry Testbed
CMOS	Complementary Metal-Oxide-Semiconductor
CPU	Central Processing Unit
DC	Direct Current
DOF	Degrees of Freedom
FPS	Frames per Second
GB	Gigabyte
HDMI	High Definition Multimedia Interface
HIL	Hardware in the Loop
HOMER	Holonomic Omni-Directional Motion Emulation Robot
IMU	Inertial Measurement Unit
JPL	Jet Propulsion Laboratory
LAN	Local Area Network
LASR	Land, Air, and Space Robotics Laboratory
LED	Light Emitting Diode
LIDAR	Light Detection and Ranging
MEMS	Micro Electro-Mechanical System
NASA	National Aeronautics and Space Administration
NEST	Navigation, Estimation, and Sensing Testbed
NUC	(Intel) Next Unit of Computing

PCM	Protection Circuit Module
RGB	Red, Green, Blue
RMS	Root, Mean, Square
ROS	Robot Operating System
SDK	Software Development Kit
SPDT	Single Pole, Double Throw (Switch)
SPST	Single Pole, Single Throw (Switch)
STEP	Suspended Target Emulation Pendulum
UNC	Unified Coarse (Thread)
USB	Universal Serial Bus
VDC	Volts Direct Current
WLAN	Wireless Local Area Network

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1. INTRODUCTION

1.1 Motivation

In the aerospace industry, computer algorithms are responsible for many tasks and are utilized in a wide range of applications. For example, algorithms allow for the automated flight of commercial aircraft via the autopilot function, they navigate and guide space vehicles into a desired orbit, and they stabilize the flight of small-scale consumer drones; these few examples provide only a narrow window into the far reaching utilization of algorithms in the aerospace industry. When new algorithms are developed, they are first validated before being deployed to their respective applications in order to ensure their performance is as desired and to characterize the conditions under which the algorithms fail. Algorithm validation can be carried out in a variety of manners and to a range of extents; to facilitate a discussion about the algorithm validation process, a hypothetical algorithm is proposed and will be considered throughout this introduction. Consider the development of a hypothetical navigation algorithm which estimates the motion of some vehicle - a car, plane, spacecraft, or other vehicle - by analyzing images captured by a camera mounted on the vehicle; the input to this algorithm is a sequence of images and the output is an estimate of the vehicle's motion. The development of such an algorithm is an active area of research.

One possible approach for testing this hypothetical navigation algorithm is with the use of a computer simulation. To test the algorithm entirely within a computer simulation, multiple elements need to be simulated: the dynamics and motion of the vehicle, the camera, and the environment in which the vehicle is moving. The creation of a high-fidelity computer simulation that accurately models these elements requires extensive development. Simulation of the vehicle's motion requires an accurate dynamic model of the vehicle. Simulation of the camera requires careful construction of a mathematical model for each of the camera's components - the sensor, aperture, shutter, and lens - and the resulting field-of-view, exposure time, dynamic range limits, and depth-of-field, as well as specific effects like lens distortion, motion blur, and sensor noise. Simulation of the environment requires the generation of environment geometry, application of surface textures to the geometry, consideration of light sources and the reflectivity of surfaces, and identification of the surfaces that are viewable from a given camera pose. Clearly, the construction of a high-fidelity computer simulation to test this algorithm is a non-trivial task.

Furthermore, the overall fidelity of the constructed computer simulation is a function of the accuracy of the mathematical models used to describe the individual elements of the simulation. A high-fidelity simulation requires accurate mathematical models, which can be complex and require extensive development to implement. Even in the most complex models, the physics of the modeled systems are often idealized to some degree, and the resulting computer models do not perfectly capture the true physics of the real systems. The burden of developing a computer simulation can be lessened by decreasing the fidelity of the constructed simulation; in the provided example, this equates to implementing more simplistic mathematical models of the vehicle, camera, and environment. This lower-fidelity simulation may provide some validating results while lowering the cost of development. Unfortunately, while low-fidelity simulations may be valuable during the early stages of algorithm development, they do not provide the confidence needed to certify algorithms for deployment.

As an alternative to the use of computer simulations for the validation of algorithms, the testing and validation of algorithms can be carried out on true hardware in actual operating conditions. In the case of the hypothetical navigation algorithm previously considered, this equates to mounting a real camera to the actual vehicle to be navigated, operating the vehicle within a real environment, capturing images of the environment as the vehicle moves, and running the navigation algorithm to process the real images that were captured to produce a navigation solution. This type of approach circumvents the extensive development required to construct high-fidelity computer simulations and allows for thorough algorithm testing with true physics instead of the idealized physics used within all computer simulations.

Despite these benefits, testing on true hardware has some disadvantages when compared to computer simulations. One disadvantage is the inability to control all conditions of the testing environment, which is an invaluable asset when evaluating how an algorithm's performance varies with changes in a specific operational condition. A lack of control over the testing environment can also potentially lead to safety risks for developers and the general public should the algorithm malfunction or perform poorly. These disadvantages are not present with computer simulations, where the testing environment can be controlled completely and no physical hardware is involved.

The temporal and monetary costs of testing on true hardware and in actual operating conditions are even more fundamental limitations of such an approach. Hardware must first be designed and manufactured before any testing of algorithms can be carried out, precluding the possibility of parallel development of the hardware and algorithms. Hardware may be damaged during testing due to poor algorithm performance or malfunction, requiring replacement of the hardware. Additionally, test hardware may require replacement due to the more straight-forward reason that true operation consumes the hardware - as is the case with single-use orbital launch vehicles and terminal-trajectory missiles. In cases where the hardware is expensive to manufacture, the production of multiple sets of hardware can become cost prohibitive. In cases where true operation is expensive - as is the case with spacecraft due to the cost of putting mass into orbit - it may simply be too costly to carry out test runs.

A middle ground exists between the approaches of full computer simulation and true operation for the testing of algorithms, where a computer simulation is augmented with actual hardware in what is known as a hardware-in-the-loop (HIL) simulation. In a HIL simulation, real hardware is used in place of computer models for specific elements of the system, while other elements of the system remain modeled within the computer. The use of real hardware substitutes real physics in place of the idealized physics of the previously simulated elements and increases the overall fidelity of the simulation. It may also reduce the overall development burden if procuring or manufacturing the real or representative hardware for an element is simpler than constructing a high-fidelity computer model of the same element. Additionally, developers retain control over the testing environment since certain elements remain modeled within the computer and the system exists within the laboratory space. This allows for rapid testing of algorithms in a range of operating conditions and minimizes the potential for hardware damage and safety hazards that are present with testing via true operation. HIL testing often serves as an intermediate step in the development cycle of algorithms, and exists between preliminary tests with low-fidelity simulations and final certification on true hardware in actual operating conditions. The maturation of an algorithm via HIL testing prepares it for final testing and deployment, and minimizes the inherent risks that come with true operation. In the case of academic research into new algorithms - where the goal is not the development of a tangible product but development of the algorithm itself - HIL simulations with representative hardware sometimes serve as the final method of evaluation.

With respect to the navigation algorithm previously considered, one realization of a HIL simulation might be the construction of a mock environment within the laboratory and the physical manipulation of a real camera to move the camera around the mock environment. The vehicle and the vehicle's motion would remain simulated by the computer, and the real camera would be physically manipulated to create motion that is representative of that which would be experienced if it were mounted on the simulated vehicle. Such an approach increases the fidelity of the simulation while circumventing the overhead of developing computer models for the camera and environment.

Many organizations employ HIL testing as an important step in the development and implementation of new algorithms, and facilities exist around the world to support HIL testing. One such governmental organization is NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, which has made use of multiple HIL testbeds in their development of interplanetary robotic spacecraft. JPL's Camera Gantry Testbed (CGT) has been used for small-scale laboratory emulation of orbital and landing trajectories to test spacecraft landing algorithms. The CGT has a motion controller which provides a camera with five degree-of-freedom (DOF) motion over a simulated planetary surface, and is capable of translating the camera within the volume of the gantry while also rotating it along two axes. Images of the simulated planetary surface are acquired by the camera and processed by machine-vision algorithms to produce navigation and guidance solutions, which are then fed back to the CGT's motion controller to prescribe a specific motion to the camera - "closing the loop". The true location and orientation of the camera within the CGT is independently known and can be used for validating the navigation solutions produced by the machine-vision algorithms [1]. JPL also makes use of a separate, higher-fidelity HIL testbed - the Autonomous Helicopter Testbed - which is similarly used to develop planetary landing technologies and serves as a step up from the CGT [2].

Private companies also make use of HIL simulations in support of algorithm development; the Space Operations Simulation Center at Lockheed Martin's Waterton Campus in Littleton, Colorado is a clear example of this. The Space Operations Simulation Center is a facility that supports the testing and characterization of guidance, navigation, and control algorithms and hardware for multiple projects, including the testing of the Orion Crew Module's relative navigation system via rendezvous simulations using a large 6-DOF robot and full-sized vehicle mock-ups [3]. The utilization of HIL simulations for algorithm validation has not remained limited to use by large governmental organizations and private companies but has also made its way into academia where it is used as a means to create medium-fidelity simulations to support algorithm research. The Robust Robotics Group at the Massachusetts Institute of Technology, the Bio-Inspired Perception and Robotics Laboratory at the University of Colorado at Boulder, and the Aerospace Robotics Laboratory at Stanford University are examples of academic organizations that currently employ or have employed HIL simulations to support algorithm research [4][5][6].

The Land, Air, and Space Robotics Laboratory (LASR) - operated by the Department of Aerospace Engineering at Texas A&M University in College Station, Texas - is an organization that conducts research in the areas of autonomous vehicles, vehicle proximity operations, multi-vehicle swarms, computer vision, and guidance, navigation, and control, amongst others. Research in these areas often leads to the development of new algorithms and the refinement of existing algorithms - products which must be tested and validated before they are published. Similar to the organizations previously mentioned, LASR uses robotics to develop HIL simulations for the meaningful testing and validation of these algorithms [7]. The robots developed and deployed at LASR are used to emulate vehicles and their motion, as well as the dynamics of special operational environments - such as low-gravity environments.

LASR has developed multiple robots to achieve motion within the laboratory space. Two noteworthy robots - the Holonomic Omni-Directional Motion Emulation Robot (HOMER) and the Suspended Target Emulation Pendulum (STEP) - are multi-axis robots that are designed to carry a payload and give that payload some desired motion. HOMER is a ground-traversing robot that is capable of untethered 6-DOF motion across the entire floor space of the lab, while STEP is a ceiling-mounted, actively-controlled pendulum that is capable of limited 5-DOF motion [8][9]. Both HOMER and STEP have been widely used to conduct HIL testing of algorithms at LASR.

For the various projects in which HOMER and STEP have been utilized, custom payloads have been built to meet the specific needs of the given projects. Often, the custom payloads have similarities in their function and form, and are routinely used as mobile data collection platforms. They contain one or more inertial and environmental sensors and a computing unit of varying capability. Additionally, software is developed for the custom payload to operate the specific sensors on the specific computing unit to meet the needs of the project. In some cases the data collected by the custom payload must be transmitted over a local network where it is processed by a more powerful machine in real time; this data transfer may be wired or wireless, depending on the specific needs of the project. Though in other cases, data is not transmitted at all, but is processed directly onboard the custom payload or stored onboard for later transfer to a separate machine for post-processing. In some applications, electrical power for the custom payload is provided over tethering cabling, yet in others an onboard battery provides power. The custom payload for each project is tailored to the specific sensing, computing, and operational needs of the project.

The design and construction of these custom payloads demands a significant time investment from researchers, and time spent on this overhead development reduces the time researchers have available for algorithm research. Since researchers are motivated to make progress on algorithm research and not on overhead development, often the minimum necessary effort is made towards developing custom payloads. This leads to laboratory resources being designed with only the target project in mind, and the applicability of existing custom payloads to future projects is often limited. Future researchers must then spend time and money developing a new custom payload before they can progress their algorithm research, and the cycle continues. This cyclic, recurring burden of developing custom laboratory resources presents an opportunity to reduce the future overhead burden of conducting research at LASR while increasing the efficacy of LASR resources.

For this thesis, a new robotic platform - the Navigation, Estimation, and Sensing Testbed (NEST) - was developed to serve as a robust and reusable payload for use with HOMER, STEP, and other laboratory robots when conducting HIL simulations. With utility and reusability as core guiding principles, NEST was designed to fulfill the needs of multiple active projects - both at LASR and partner organizations' laboratories - as well as future projects whose needs are presently unknown. The remainder of this chapter details the specific requirements that drove the design of NEST and concludes with a brief overview of the final engineering solution. The subsequent chapters of this document address the specific details of NEST's subsystems, the typical usage of NEST within the laboratory setting, and the ongoing development of NEST.

1.2 Design Criteria

Before NEST was designed, it was known that the final engineering solution would be applied to two active projects within LASR. The application of NEST to these projects was carefully considered and a set of design criteria was formalized to ensure the final engineering solution would satisfy the needs of both projects. Furthermore, the needs of future projects were anticipated and the set of design criteria was expanded and generalized to encourage the longevity of NEST. Table 1.1 lists the design criteria around which NEST was designed.

NEST Design Criteria	
1. Sensor Requirements	
1.1	Must support the operation of a single IMU, with accommodations for both the VectorNav VN-100 and VN-300 models.
1.2	Must support the operation of the Stereolabs ZED stereo camera.
1.3	Must support the operation of the Basler acA1300-200uc monocular color camera.
1.4	Must support the operation of the ASUS Xtion Pro Live RGB and depth camera.
1.5	Must support the operation of the Texas Instruments OPT8241-CDK-EVM LIDAR evaluation module.
2. Computing Requirements	
2.1	Must have Linux Ubuntu 16.04 as the operating system.
2.2	Must have the ability to run Robot Operating System (ROS) - Kinetic Kame.
2.3	Must have sufficient processing power to simultaneously run the IMU at 200 hertz plus any combination of (2) of the following four sensors at 30 hertz: ZED camera, acA1300-200uc camera, Xtion camera, OPT8241-CDK-EVM LIDAR module.
3. Networking Requirements	
3.1	Must have the ability to be networked through a gigabit LAN port.
3.2	Must have the ability to be networked through a WLAN using the 802.11ac protocol.
4. Run-time Operational Requirements	
4.1	Must have the ability to initiate sensor data acquisition directly through terminal commands on NEST's operating system.

Table 1.1: Design criteria for the NEST platform.

NEST Design Criteria	
4.2	Must have the ability to remotely initiate sensor data acquisition from a networked machine.
4.3	Must have the ability to store raw sensor data and/or processed data onboard in non-volatile memory.
4.4	Must have the ability to transmit raw sensor data and/or processed data to a separate machine over a network.
5. Power Requirements	
5.1	Must have the ability to be powered by an external power source through a non-permanent and easily attachable/detachable connection.
5.2	Must have the ability to be powered by a permanent, internal battery without the use of external umbilical cabling.
5.3	Must have the ability to easily switch between external and internal power sources without the need to disassemble components or rewire electrical connections.
5.4	Must have the ability to switch between external and internal power sources without a discontinuity in power provision.
5.5	Must have overcurrent protection on all power sources and voltage converters.
5.6	Must be capable of running solely on battery power for a minimum of 3 hours.
6. Physical Requirements	
6.1	Must be mountable to existing motion robots at LASR - including STEP and HOMER; a mounting adapter may be utilized.
6.2	Must be mountable to the High Sight Pro cable cam trolley; a mounting adapter may be utilized.
6.3	Must have a maximum weight not exceeding 7.26 kg (16 lbm).

Table 1.1 Continued.

1.3 NEST Overview

The Navigation, Estimation, and Sensing Testbed (NEST) - shown in Figure 1.1 - is a highly-reusable robotic platform which aids algorithm research by facilitating HIL simulations in the laboratory. NEST serves as a sensing and computing "head" - acquiring and processing data from its onboard sensors - and is intended to be used with a motion-providing robot in a laboratory setting. NEST can be immediately applied to a range of applications while requiring minimal, if any, hardware and software development before deployment.

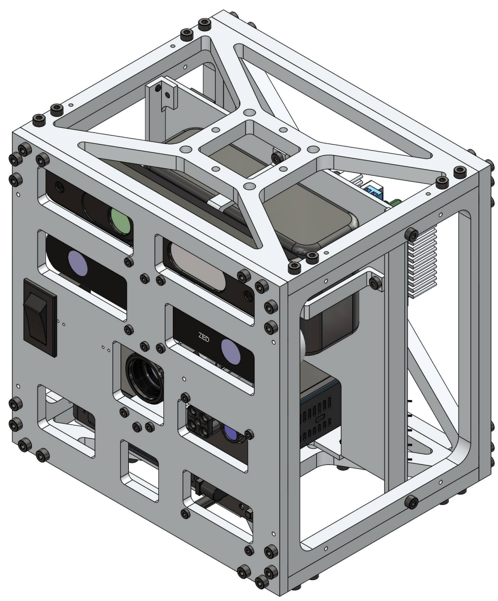

Figure 1.1: The Navigation, Estimation, and Sensing Testbed (NEST), shown without optional siding panels installed.

NEST contains a suite of inertial and environmental sensors to meet the sensing needs for a variety of applications. NEST's sensor suite is composed of three color cameras of varying imaging capability, a flash LIDAR module, and an IMU with internal accelerometer, gyroscope, magnetometer, and barometer. Additionally, NEST has electrical and mechanical accommodations for the operation of additional or alternative sensors. NEST's sensor suite and potential alternative sensors are discussed in Section 2.

NEST contains a powerful onboard computer to operate these sensors, process sensor measurements, and execute research algorithms. NEST's computer houses a 7th generation Intel i5 processor, 8 gigabytes of memory, and a 250 gigabyte solid-state drive, and can be upgraded with additional memory up to 32 gigabytes and/or additional storage up to the limits of manufacturing - 2 terabytes at the time of writing. Additionally, NEST's computer is manufactured with a standard chassis form factor, and can be replaced with a more powerful unit of the same chassis form factor; alternate units are available with processors up to an 11th generation Intel i7 CPU. NEST's computer is discussed in Section 3.

To power the onboard computer and sensors, NEST has an internal, rechargeable battery capable of powering NEST for many hours. Additionally, NEST can be operated indefinitely on an external power source, and can switch between internal and external power sources without requiring NEST be shutdown. NEST's electrical design is discussed in Section 4, and Appendix B contains detailed electrical drawings.

NEST's sensors, computer, battery, and power electronics are packaged within a 21.8 x 21.8 x 17.3 centimeter cube-shaped aluminum chassis, with a total assembly weight of approximately 6.4 kilograms (14.1 lbm). The overall assembly was designed in a modular fashion, allowing for easy disassembly for maintenance or sensor replacement. Additionally, the chassis contains multiple mounting points for the mounting of NEST to motion-providing robots in the laboratory. The mechanical design of NEST is discussed in Section 5, and Appendix A contains detailed mechanical drawings for all of NEST's assemblies and nonstandard parts.

Software was developed to operate NEST's sensors and facilitate the transmission and storage of sensor measurements. The development of additional software will be an ongoing task that spans the life of NEST. Section 6 discusses the general principles guiding NEST's software development, and Appendix C contains sample code to give the reader some insight into NEST's software.

Section 7 provides the reader with examples for the typical usage of NEST in the laboratory, including the implementation of NEST as part of a multi-machine laboratory setup for conducting HIL simulations. Section 8.1 briefly discusses potential future work on NEST.

2. SENSORS

The utility of NEST as a multipurpose and reusable platform is founded on its ability to meet the sensing needs for a variety of applications. NEST's ability to fulfill the varied sensing needs of a range of applications is made possible by the broad sensing capability provided by its suite of onboard sensors. The design criteria listed in Section 1.2 mandated that NEST have accommodations for operating a set of five predesignated sensors whose selections were based on the immediate and anticipated needs of LASR; this set of predesignated sensors constitute the sensor suite around which NEST's overall design was driven. Table 2.1 presents an overview of NEST's sensor suite, while Sections 2.1 - 2.5 provide detailed information and select specifications for each of the sensors.

Sensor	Description
ZED Camera	High-resolution, wide field-of-view, stereo color camera
acA1300-200uc Camera	High-frame-rate, variable focal length (changeable lens), monocular color camera
Xtion Camera	Combination monocular color and infrared structured-light depth camera
OPT8241 LIDAR Module	Time-of-flight flash LIDAR camera
VN-100 IMU	Inertial measurement unit, with built-in accelerometer, gyroscope, magnetometer, and barometer

Table 2.1: Overview of NEST's sensor suite.

Full documentation for each of the predesignated sensors is available from the manufacturers, but was omitted from this document due to length; the reader is encouraged to independently investigate the full documentation for each sensor. NEST's utility as a reusable platform is furthered by the option to swap out any or all of the predesignated sensors for alternative sensors while reusing the same mechanical, electrical, and computing resources provided by NEST. Section 2.6 presents a limited discussion of potential alternative sensors.

2.1 ZED Stereo Color Camera

The ZED camera by Stereolabs - shown in Figure 2.1 - is a wide field-of-view, high-frame-rate, high-resolution, stereo camera with a 120 millimeter baseline. With a maximum resolution of 2208 x 1242 pixels per lens and a 90° horizontal by 60° vertical field-of-view, the ZED camera has the highest resolution and largest field-of-view between NEST's three color cameras. Programmable camera parameters allow for adjustments in resolution, frame rate, exposure time, brightness, contrast, saturation, gamma correction, and white balance. Multiple operational modes allow for stereo video capture at various resolutions and frame rates, ranging from 2208 x 1242 resolution at 15 hertz capture rate to 672 x 376 resolution at 100 hertz capture rate; Table 2.2 summarizes the various video capture modes. The ZED camera is compact and lightweight - weighing only 135 grams and measuring 175 by 30 by 33 millimeters - and can be mounted via a single 1/4"-20 UNC internally thread hole. It is powered over USB via its connection to a host computer, and consumes 1.9 watts (360 milliamps, 5 volts) of power [10]. Specifications of the ZED camera are summarized in Table 2.3.

Figure 2.1: ZED camera. Figure reprinted from [10].

Video Mode	Output Resolution (Per Lens)	FPS
2.2k	2208 x 1242	15
1080p	1920 x 1080	30
720p	1280 x 720	60
WVGA	672 x 376	100

Table 2.2: ZED camera video capture rates at various imaging resolutions. Table reprinted from [10].

Specification	Value
Camera Type	Stereo Color
Field-of-View	90° H x 60° V
Maximum Resolution	2208 x 1242 pixels
Stereo Baseline	120 mm
Input Voltage	5 V (power via USB)
Current Draw	380 mA
Power Consumption	1.9 W
Dimensions	175 x 30 x 33 mm
Weight	135 g

Table 2.3: Select specifications of the ZED camera. Table adapted from [10].

2.2 acA1300-200uc Monocular Color Camera

The acA1300-200uc camera by Basler - shown in Figure 2.2 - is a high-frame-rate, monocular, color camera with a CMOS sensor and global shutter. With a resolution of 1280 x 1024 pixels and a frame rate of up to 203 FPS, the acA1300-200uc is NEST's highest frame rate camera. The acA1300-200uc allows for various lenses to be attached, giving a range of options with respect to field-of-view and zoom; with an appropriate lens, the acA1300-200uc provides the densest pixel resolution between NEST's cameras. The acA1300-200uc is powered over USB via its connection to a host computer, consumes 3 watts (600 milliamps, 5 volts) of power, and measures 29.3 x 29 x 29 millimeters - making it the most compact camera onboard NEST [11]. Specifications for the acA1300-200uc camera can be found in Table 2.4. A 25 millimeter fixed focal length lens was attached to the acA1300-200uc; specifications for the lens are listed in Table 2.5. Additionally, the acA1300-200uc is serviced by Basler's Pylon API, which gives users control over the camera's various image capture parameters [12].

Figure 2.2: acA1300-200uc camera (left); acA1300-200uc camera with attached lens (right). Figure reprinted from [11].

Specification	Value
Camera Type	Monocular color
Sensor Type	CMOS
Shutter Type	Global
Maximum Resolution	1280 x 1024 pixels
Pixel Depth	10 bits
Maximum Frame Rate	203 FPS
Input Voltage	5 V (power via USB)
Current Draw	600 mA @ 5 V
Power Consumption	3 W
Dimensions	29.3 x 29 x 29 mm
Weight	80 g

Table 2.4: Select specifications of the acA1300-200uc camera. Table adapted from [11].

Specification	Value
Lens Type	Fixed focal length
Focal Length	25 mm
Aperture	f / 1.4
Field-of-View	14.4°
Working Distance	100 mm - ∞
Diameter	31 mm
Length	30.5 mm
Weight	49 g

Table 2.5: Select specifications of the Edmund Optics 59871 C-Series 25mm fixed focal length lens. Table adapted from [13].

2.3 Xtion Monocular Color and Infrared Depth Camera

The Xtion Pro Live (Xtion) camera by ASUS - shown in Figure 2.3 - is a combination monocular color camera and infrared depth sensor. Having roots in the digital entertainment and gaming industry, the Xtion was originally developed for real-time motion tracking of user's gestures and whole-body poses for gaming and consumer application development [14]; a comparable sensor is Microsoft's Kinect. The collection and correlation of color image and depth data in a single integrated sensor, along with its relatively cheap price, makes the Xtion an attractive, low-cost sensor for laboratory research. The Xtion has been utilized in past projects at LASR, and was included in NEST as a legacy sensor. Select specifications for the Xtion are listed in Table 2.6.

Figure 2.3: Xtion camera. Figure reprinted from [14].

Specification	Value
Camera Type	RGB & Depth
Field-of-View	58° H x 45° V
RGB Image Resolution	1280 x 1024 pixels
Depth Image Resolution	640 x 480 pixels
Depth Range	0.8 - 3.5 m
Input Voltage	5 V (power via USB)
Current Draw	< 500 mA
Power Consumption	< 2.5 W
Dimensions (with base)	180 x 35 x 50 mm

Table 2.6: Select specifications of the Xtion camera. Table adapted from [15].

2.4 OPT8241-CDK-EVM LIDAR Module

The OPT8241-CDK-EVM LIDAR evaluation module by Texas Instruments - shown in Figure 2.4 - combines an infrared illuminator and camera to form a 3D, time-of-flight, flash LIDAR sensor. The OPT8241-CDK-EVM is capable of providing a depth measurement for each pixel in a 320 x 240 image at a rate of 60 hertz and is highly configurable, allowing users the ability to tailor the OPT8241-CDK-EVM's performance to a particular application. The illumination board consists of 850 nanometer infrared lasers with diffusers and a laser driver circuit, and has an adjustable output power within the range of 4 to 10 watts. The sensor board houses the sensor, an on/off switch, indicator LEDs, and ports for connection to a power supply and computer. Additionally, the OPT8241-CDK-EVM LIDAR evaluation module is serviced by the Voxel SDK [16]. Specifications for the OPT8241-CDK-EVM are listed in Table 2.7.

Specification	**Value**
Sensor Type	Time-of-flight
Field-of-View	74.4° H x 59.3° V
Resolution	320 x 240 pixels
Frame Rate	60 FPS
Illumination Wavelength	850 nm
Range	4 m
Power Consumption	< 15 W
Dimensions	88.8 x 60 x 24.3 mm

Table 2.7: Select specifications of the OPT8241-CDK-EVM LIDAR evaluation module. Table reprinted from [16].

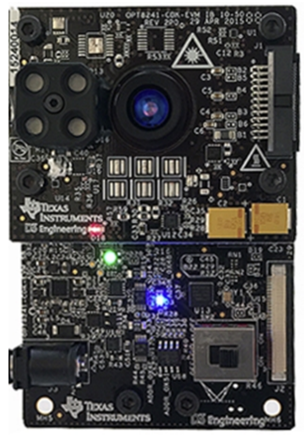

Figure 2.4: OPT8241-CDK-EVM LIDAR evaluation module. Figure reprinted from [17].

2.5 VN-100 Inertial Measurement Unit

The VN-100 inertial measurement unit (IMU) by VectorNav - shown in Figure 2.5 - is a lightweight, low-power, high-performance MEMS sensor that combines a 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer, barometer, and accompanying circuitry within a durable, miniature, anodized aluminum enclosure. The VN-100 is capable of outputting raw or corrected measurements at up to 800 hertz or real-time orientation solutions at up to 400 hertz using a built-in, quaternion-based extended Kalman filter [18]. Mechanical and electrical specifications for the VN-100 are listed in Table 2.8. Table 2.10 lists orientation solution specifications provided by the internal extended Kalman filter. Select specifications for the accelerometer, gyroscope, magnetometer, and barometer are listed in Table 2.9.

Figure 2.5: VN-100 IMU. Figure reprinted from [18].

Specification	Value
Input Voltage	4.5 V - 5.5 V (power via USB)
Current Draw	40 mA @ 5 V
Max Power Consumption	220 mW
Digital Interface	Serial TTL, RS-232
Baud Rate	Up to 921600
Connector	Harwin M80-5001042
Dimensions	36 x 33 x 9 mm
Weight	15 g

Table 2.8: Select physical and electrical specifications of the VN-100 IMU. Table adapted from [19].

Specification	Value
Accelerometer	
Range	$\pm$ 16 g
Resolution	< 0.5 mg
Noise Density	< 0.14 mg/$\sqrt{Hz}$
In-Run Bias Stability	< 0.04 mg
Internal Alignment Error	$\pm$ 0.05°
Gyroscope	
Range	$\pm$ 2000°/s
Resolution	< 0.02°/s
Noise Density	< 0.0035°/s $\sqrt{Hz}$
In-Run Bias Stability	< 10°/hr
Internal Alignment Error	$\pm$ 0.05°
Magnetometer	
Range	$\pm$ 2.5 gauss
Resolution	1.5 milligauss
Noise Density	140 μgauss/$\sqrt{Hz}$
Internal Alignment Error	$\pm$ 0.05°
Barometer	
Range	10-1200 mbar
Resolution	0.042 mbar
Accuracy	$\pm$ 1.5 mbar
Error Band	$\pm$ 2.5 mbar

Table 2.9: Select specifications of the VN-100's internal accelerometer, gyroscope, magnetometer, and barometer. Table adapted from [19].

Specification	Value
Range: Heading/Roll	± 180°
Range: Pitch	± 90°
Angular Resolution	< 0.05°
Static Accuracy (Heading, Magnetic)	2.0° RMS
Static Accuracy (Pitch/Roll)	0.5° RMS
Dynamic Accuracy (Heading, Magnetic)	2.0° RMS
Dynamic Accuracy (Pitch/Roll)	1.0° RMS
Repeatability	<0.2°
Output Rate (Raw Sensor Data)	800 Hz
Output Rate (Attitude Data)	400 Hz

Table 2.10: Select specifications of the VN-100's internal, quaternion-based attitude and heading outputs. Table adapted from [19].

2.6 Additional or Alternative Sensors

NEST is not limited to operating only the five predesignated sensors around which it was initially designed, but is capable of operating any additional or alternative sensor that can be serviced by the electrical resources (Section 4, Appendix B), mechanical resources (Section 5, Appendix A), and computing resources (Sections 3, 6) provided by NEST. The details of these resources are addressed fully in their respective sections, so only a limited summary is provided here.

NEST's onboard computer has five USB ports through which sensors can be connected. One USB port has been reserved for the connection of a mouse and keyboard via a USB hub, limiting the number of ports available for sensors to five; if a mouse and keyboard are not needed, all six ports can be used for connecting sensors. The final configuration of NEST's sensor suite after any sensor additions or substitutions is limited by the number of available USB ports. It may be possible to operate more sensors than can be connected directly to the computer's available USB ports by routing multiple sensors through a single USB port via a hub, though the viability of such a configuration has not yet been explored. Since NEST's onboard computer is a fully-functioning desktop machine and runs the Linux Ubuntu operating system, software is not a limiting factor for alternative sensors, except for those that cannot be operated on NEST's operating system.

For the powering of additional or alternative sensors, NEST's computer can provide limited power at 5 volts DC to sensors that can be powered via USB, which is the case for many low-power sensors and four of NEST's five predesignated sensors. Additionally, NEST has a dedicated voltage converter for sensors that require more power than the computer can deliver or for sensors that require power at a different voltage than is available from the computer. This voltage converter has an adjustable output voltage that can be tuned within the range of 1.2 - 21 volts DC and can output up to 8 amps / 100 watts. With minor modifications to NEST's wiring, the voltage converter can be bypassed and sensors may be powered directly from the battery, effectively increasing the voltage range upper limit to 24 volts DC.

The sensor mounting plate on which NEST's five predesignated sensors are mounted was designed to compactly fit the predesignated sensors and does not have room for additional sensors. Should one of the predesignated sensors be replaced with an alternative sensor, the mounting of the alternative sensor must utilize the same sensor mounting plate mounting holes as the replaced sensor, otherwise a new sensor mounting plate must be designed and manufactured to accommodate the alternative sensor; this can be accomplished with the use of a mounting adapter. Additional or alternative sensors can also be mounted to the exterior of NEST via the bolt patterns on the top, back, and bottom chassis parts. NEST can be mounted to external structures via one of these faces, leaving the remaining two faces free for the mounting of sensors.

3. COMPUTER

Many options were considered for NEST's onboard computer; the considered options ranged from units as small as microprocessor-based, single-board computers to as large as full-scale, CPU-based systems with auxiliary graphics processing units that resemble a desktop system built by a computer enthusiast. Most options satisfied many of the design criteria with their ability to run Linux Ubuntu 16.04 and ROS Kinetic, along with their built-in wireless networking capability, so the decision of which computer to incorporate into NEST was largely driven by the need to find a balance between processing power, physical size, and power consumption. The Intel Next Unit of Computing (NUC) - shown in Figure 3.1 - was chosen due to its relatively compact size, greater than average processing power, CPU-based architecture, and flexibility with memory and storage options.

Figure 3.1: Intel NUC, shown with short form factor chassis. Figure reprinted from [20].

The NUC can be purchased in a variety of hardware and software configurations, all of which fall into one of two categories: "plug-and-play" units which are ready-to-operate computers and do not require modifications from the user, and "kits" which require hardware and software additions before they can be operated. Plug-and-play units are shipped from the vendor with all required hardware components installed within the NUC chassis, and arrive with a pre-loaded Windows operating system; the user simply needs to power the unit and it is ready to compute. The kit, however, only contains the motherboard, mounted processor, and chassis, but does not arrive with any installed memory or storage; the user must independently acquire and install these components. Additionally, the user must acquire and install their desired operating system before the kit configuration can be operated.

Specification	Value
Processor Model No.	i5-7260U
No. Processor Cores	(2)
No. Processor Threads	(4)
Processor Base Frequency	2.2 GHz
Max Turbo Frequency	3.4 GHz
Memory Type	DDR4-2133 1.2V SO-DIMM
No. Memory Channels	(2)
Maximum Memory Capacity	32 GB
Storage Interface	M.2 22 x 42/80
USB Ports	(4) USB 3.0 via external headers; (2) USB 2.0 via internal pins
# No. HDMI Ports	(1)
# No. Thunderbolt™ 3 Ports	(1)
Input Voltage	12-19 VDC
Processor Design Power (at base frequency)	15 W
Chassis Dimensions	115 x 111 x 35 mm
Mass (w/o Memory or Storage)	440 g

Table 3.1: Specifications of the Intel NUC NUC7i5BNK kit. Table adapted from [21].

The kit configuration of the NUC was chosen over the plug-and-play configuration because the custom selections of memory, storage, and operating system were desirable options; specifically, the NUC7i5BNK kit was chosen for its balance between processing power and cost. The NUC7i5BNK kit comes with a mounted Intel i5-7260U processor, supports up to 32 gigabytes of DDR4 memory through two memory channels, and has an M.2 interface for storage installation. Additionally, the NUC7i5BNK kit has built in 802.11ac Wi-Fi capabilities and enough USB channels to support all of the sensors dictated in NEST's design criteria [21]. Specifications of the NUC7i5BNK kit are listed in Table 3.1. To complete the NUC7i5BNK kit and transform it into a ready-to-operate computer, a single unit of 8 gigabyte memory, a 250 gigabyte solid-state drive, and Linux Ubuntu 16.04 operating system were installed. Specifications of the installed memory and storage are listed in Tables 3.2 and 3.3, respectively. The operating system and other software are discussed in Section 6. As needs change in the future, NEST's NUC can be replaced by a more powerful unit of the same form factor; currently, the most powerful NUC models contain an 11th generation i7 CPU.

Specification	**Value**
Brand	Crucial
Part No.	CT8G4SFD824A
Form Factor	SO-DIMM
Memory Type	DDR4-2400
Capacity	8 GB
Rank	Dual-Ranked
DIMM Type	Unbuffered

Table 3.2: Specifications of the memory installed in NEST's computer. Table adapted from [22].

Specification	**Value**
Brand	Western Digital
Part No.	WDS250G2B0B
Form Factor	M.2 22 x 80 mm
Storage Type	NAND SSD
Interface	SATA III 6 Gb/s
Capacity	250 GB
Sequential Read Speed (up to)	550 MB/s
Sequential Write Speed (up to)	525 MB/s

Table 3.3: Specifications of the solid-state storage installed in NEST's computer. Table adapted from [23].

4. ELECTRICAL DESIGN

NEST's computer and sensors require electrical power to operate, and the design criteria listed in Section 1.2 dictate requirements for the provision of this power. Specifically, NEST must have accommodations for operating on power from an external power supply as well as from an internal, rechargeable battery. The power source on which NEST is operating must be easily switchable between the external power supply and internal battery - or vice versa - without the need to disassemble components or rewire connections, without a discontinuity in power provision, and without requiring NEST's computer to be powered off. Finally, properly-sized overcurrent protection must be placed at appropriate locations within NEST's circuitry to protect NEST's computer, sensors, and battery against electrical faults.

To achieve this functionality, an external power supply and internal battery were connected to a common terminal and mutually isolated using diodes. The common terminal feeds voltage converters, which allow a range of input voltages from either power source and convert the input voltage into the necessary voltages for NEST's loads. The specification of NEST's external power supply, internal battery, voltage converters, and fuses first required determination of NEST's overall power requirements, which are developed in Section 4.1 and summarized in Table 4.6. Section 4.2 discusses NEST's ability to operate on power from either an external power source or an internal battery, and to seamlessly transfer between these power sources. Section 4.3 covers the specifications of NEST's internal lithium-ion battery. Finally, Section 4.4 details the overcurrent protection that guards the components of NEST against shorts and overloads. Detailed electrical drawings of NEST can be found in Appendix B, which contains a single-line diagram that compactly shows the connectivity between components as well as a detailed wiring diagram showing terminal-to-terminal wiring for all components.

4.1 Power Requirements

NEST's overall power requirements were determined by first identifying the power requirements of each of NEST's individual loads and then appropriately grouping and summing the individual load requirements. NEST's loads consist of its sensors, computer, and up to two cooling fans; the five sensors outlined in Section 2 were used for calculation of NEST's overall power requirements, though different sensors could be operated so long as they do not exceed NEST's overall power availability. The power requirements of the individual loads are captured by their input voltages, average power consumptions, and maximum instantaneous power consumptions. For all loads except the computer, the average power consumption was provided by the manufacturer; the computer's average power consumption was conservatively estimated based on the design power of the mounted CPU. For most loads, the maximum instantaneous power consumption was not provided by the manufacturer; in these cases, the maximum instantaneous power consumption was assumed to be 125% of the average power consumption. Table 4.1 summarizes the power requirements of the individual loads.

The option to power and operate all of NEST's loads simultaneously was desirable, so no duty cycle was assumed for individual loads when NEST's total power consumption was calculated.

Load Name	Input Voltage	Avg. Current	Avg. Power	Max. Power
Computer	12 - 19 VDC	1.6 A	25.0* W	40.0* W
IMU	5 VDC	40 mA	0.2 W	0.22 W
ZED Camera	5 VDC	380 mA	1.9 W	2.4† W
acA1300-200uc Camera	5 VDC	600 mA	3 W	3.8† W
Xtion Camera	5 VDC	500 mA	2.5 W	3.1† W
LIDAR Module	5 VDC	2.4 A	12 W	15 W
Cooling Fan #1	5 VDC	180 mA	0.9 W	1.1† W
Cooling Fan #2	5 VDC	180 mA	0.9 W	1.1† W

* The computer's average and instantaneous maximum power consumptions were conservatively estimated based off the CPU thermal design power.

† The instantaneous maximum power consumption was not available from the manufacturer and was assumed to be 125% of the average power consumption.

Table 4.1: Power requirements of NEST's individual loads.

The IMU, ZED camera, acA1300-200uc camera, and Xtion camera are powered over USB and receive power through their connection to the onboard computer; the computer internally converts the voltage input to the computer (12-19 volts) to the necessary 5 volts for the powering of these loads. Therefore, the power consumptions of these sensors was grouped with the computer's power consumption and considered as a single load at the computer's input voltage; this approach can be applied with any future additional or alternative sensors that may be powered through their connection to the computer. The computer's internal voltage conversion from the computer's input voltage to 5 volts is not ideal, so a conversion efficiency of 90% was assumed for the purpose of calculating the total power that must be supplied to the computer. The average and instantaneous maximum power to the computer - determined by the sum of the average and instantaneous maximum power consumption of the computer and the effective average and effective instantaneous maximum power consumptions of secondary loads powered through the computer - are summarized in Table 4.2. Loads not powered through the computer - the LIDAR module and optional cooling fans - require direct connection to a 5 volt power supply and the required power at 5 volts for these loads is summarized in Table 4.3.

The need for electrical power at two different voltages - 12-19 volts for the computer and its secondary loads, and 5 volts for all other loads - is well handled with the use of direct current voltage converters; by incorporating voltage converters, a single power source can be converted

Load Name	Voltage	Avg. Power	Max. Power
Computer	12 - 19 VDC	25.0 W	40.0 W
IMU	-	0.22* W	0.24* W
ZED Camera	-	2.1* W	2.6* W
acA1300-200uc Camera	-	3.3* W	4.2* W
Xtion Camera	-	2.8* W	3.5* W
Total		**33.4 W**	**50.5 W**

* The power consumption has been adjusted to account for the computer's internal voltage conversion with an assumed conversion efficiency of 90%.

Table 4.2: Average and instantaneous maximum power that must be supplied to the onboard computer to power the computer and secondary loads powered through the computer.

Load Name	Voltage	Avg. Power	Max. Power
OPT8241 LIDAR Module	5 VDC	12 W	15 W
Cooling Fan #1	5 VDC	0.9 W	1.1 W
Cooling Fan #2	5 VDC	0.9 W	1.1 W
Total		**13.8 W**	**17.2 W**

Table 4.3: Average and instantaneous maximum power that must be supplied to all remaining loads not powered through the onboard computer.

to the multiple internal voltages required by NEST's loads. Direct current buck converters are particularly well suited for this application because of their high efficiency and low heat generation. In contrast with linear regulators - which use a voltage divider circuit and dissipate unused power as waste heat - buck converters use a switching circuit, capacitor, and inductor to pulse-width modulate a power source and smooth the output voltage. The result is an efficient conversion with little waste and typical efficiencies near 90% or greater.

Many DC voltage converters are capable of converting a given input voltage into a range of output voltages; for these converters, the output voltage is easily adjustable and can be set by the user during system integration. Given the range of acceptable input voltages to the computer (12-19 volts) and flexibility with the output voltage of DC converters, a design decision had to be made with respect to the computer's input voltage. Since undesired resistive losses increase proportional to the square of current, it was desirable to minimize the input current to the computer; this equated to maximizing the input voltage to the computer. Therefore, the input voltage to the computer was chosen to be 19 volts. Calculation of the average and instantaneous maximum output currents for

Device	Output Voltage	Avg. Output Current	Avg. Output Power	Max. Output Current	Max. Output Power
DC Converter #1	19 VDC	1.76 A	33.4 W	2.66 A	50.5 W
DC Converter #2	5 VDC	2.76 A	13.8 W	3.44 A	17.2 W
Total			**47.2 W**		**67.7 W**

Table 4.4: Summary of required DC converter outputs.

each DC converter was then a simple exercise given the load characteristics from Tables 4.2 and 4.3. Table 4.4 summarizes the required outputs for each of the voltage converters.

DC buck converters are common electrical components and are widely available from many vendors with a variety of input/output voltage ranges and power ratings. For integration into NEST, a 100 watt buck converter by DROK was selected for its compatibility with the required outputs listed in Table 4.4. Additionally, the DROK converter's range of output voltages and total power capacity provides flexibility for additional or alternative future loads without the need to modify or replace the converters. Specifications for the selected DROK DC converter - shown in Figure 4.1 - can be found in Table 4.5.

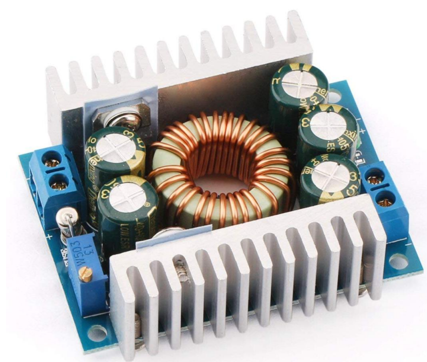

Figure 4.1: 100 watt DROK DC buck converter. Figure reprinted from [24].

Specification	Value
Input Voltage	5 - 40 VDC
Output Voltage	1.2 - 36 VDC
Continuous Output Current	8 A
Instantaneous Max Output Current	12 A
Rated Power (Stock Cooling)	100 W
Rated Power (Enhanced Cooling)	200 W
Typical Efficiency (Input: 24 V, Output: 19 V / 6 A)	94%
Dimensions	60 x 50 x 20 mm

Table 4.5: DROK DC buck converter specifications. Table adapted from [24].

The output voltage of the DROK DC converter is adjustable and can be tuned by the user to a specific value within the range of 1.2-36 volts DC [24]. Within limitations, the converter will then automatically hold the output voltage at the designated value independent of the input voltage or output current; the input voltage need not be fixed nor specified by the user and may freely fluctuate within an allowable range. However, the output voltage is constrained to be lower than the input voltage less a conversion voltage drop, and the minimum difference between the DC converter input and output voltages is a function of the input voltage, output voltage, output current, and duty cycle limitations of the converter. In lieu of a detailed analysis of the DROK converter and for the purposes of incorporation into NEST, the minimum difference between the DC converter input and output voltages was assumed to be 3 volts. Given the maximum required output voltage of 19 volts, the required minimum input voltage to the converter is 22 volts, which is the required minimum voltage for any power source supplying NEST.

The power source supplying NEST also has a 30 volt upper limit imposed by the selected switches and overcurrent protection. With minimum and maximum voltages identified, the power source requirements were completed with the identification of total power delivery requirements. NEST's average and instantaneous maximum power consumption can be calculated as the sum of the DC converter inputs. The DC converter power inputs are equal to the converter outputs divided by an assumed conversion efficiency, which varies based on input voltage, output voltage, and total transformed power. A conversion efficiency of 90% was assumed for the calculation of NEST's power consumption, which is consistent with the typical efficiencies listed for the DROK converter in Table 4.5. From Table 4.4, the summed average output power of the converters is 47.2 watts, and the summed maximum instantaneous output power is 67.7 watts. Applying a conversion efficiency of 90% to these values gives required average and instantaneous maximum power inputs of 52.4 watts and 75.2 watts, respectively, which are the power delivery requirements of any power source supplying NEST. These power delivery requirements are summarized in Table 4.6 along with the identified minimum and maximum voltages.

Specification	Value
Minimum Voltage	22 VDC
Maximum Voltage	30 VDC
Minimum Continuous Power Rating	52.4 W
Minimum Instantaneous Power Rating	75.2 W

Table 4.6: NEST power source requirements.

4.2 Power Source Flexibility

Per the design requirements listed in Section 1.2, NEST must have the ability to be powered by an external, non-permanent power source or by a permanent, internal, rechargeable battery. Additionally, any switching between power sources must not cause a discontinuity in power provision or require that NEST be powered off. Alternatively stated, if at any time while NEST is operating on external power it is desired that the power source be switched from external power to internal battery power, NEST should not need to be shut down for the switch in power sources to be made, and the switch should not cause a discontinuity in power provision such that NEST spontaneously shuts down. The converse - a switch from internal battery power to external power - should also not require shutdown or cause a discontinuity in power provision.

Accommodations for a seamless transition between power sources was accomplished by feeding both the external power source and internal battery to a common terminal and electrically isolating the power sources from each other using diodes. The use of diodes to mutually isolate the external and internal power sources protects each source from the potential application of a reverse voltage by the other source while allowing continuous power provision from either source. If at any point exactly one power source is active, a forward voltage is applied to that power source's respective diode, the common terminal becomes energized, and NEST is powered by the active power source; the inactive power source is electrically isolated from the active power source and is unaffected. If the inactive power source becomes active at any point while exactly one power source is already active such that both power sources are simultaneously active, only the diode with a forward voltage - and so the power source with the larger instantaneous voltage, allows current to pass, and NEST is powered by the power source with the larger instantaneous voltage. If at any point while both power sources are active either of the power sources becomes inactive, the remaining power source carries the load and NEST remains powered. These properties allow a continuous delivery of power to NEST through any number of power source switches so long as both sources are momentarily active during a switch; this effectively allows infinite operation of NEST. To assist with visualizing the circuit, Figure 4.2 shows a portion of NEST's single-line diagram with the forwarding of the external and internal power sources to a common terminal; a complete single-line diagram is contained in Appendix B. A voltage drop of approximately 0.7 volts occurs across the diodes, and this voltage drop was lumped with the voltage drop across the voltage converters when specifying the power source requirements in Section 4.1.

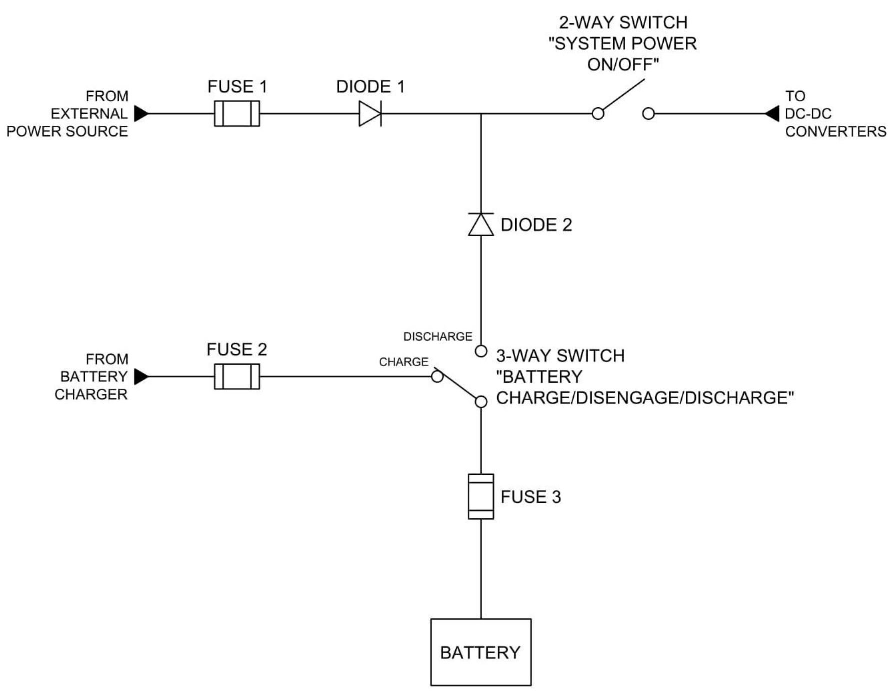

Figure 4.2: A portion of the single-line diagram showing the electrical isolation of the external and internal power sources. Additionally, overcurrent protection on the power sources is shown.

4.3 Internal Battery

From the power source specifications in Table 4.6, any battery incorporated into NEST must have a run-time voltage between 22 and 30 volts DC and be able to supply a sustained, average power of 52.4 watts and an unsustained, instantaneous maximum power of 75.2 watts. Per the design requirements in Section 1.2, NEST must be able to operate for a minimum of 3 hours on battery power, which with an average power consumption of 52.4 watts, necessitates a battery with no less than 157.2 watt-hours capacity. For the purposes of specifying battery requirements, a safety factor of 2 was incorporated and the battery's minimum sustained power output was taken as 200% of NEST's peak power consumption. This safety factor ensures the safe operation of the battery and protects against any errors that may have been present in the calculation of NEST's power consumption. Given NEST's maximum instantaneous power consumption of 75.2 watts, the battery must have a minimum sustained power output of 150.4 watts. These battery requirements are summarized in Table 4.7.

Specification	**Value**
Minimum Voltage	22 VDC
Maximum Voltage	30 VDC
Minimum Continuous Discharge Power	150.4 W
Minimum Capacity	157.2 Wh

Table 4.7: Specification requirements of NEST's internal battery.

A 25.2 volt, 6.7 amp-hour custom lithium-ion battery with a maximum continuous discharge rate of 7 amps was selected for incorporation into NEST; specifications for the selected battery - shown in Figure 4.3 - are listed in Table 4.8. With a capacity of 168.8 watt-hours and a maximum sustained output power of 176.4 watts, the battery exceeds both the capacity and rate requirements listed in Table 4.7. The selected battery has an integrated protection circuit module (PCM) which limits the voltage of the battery during charging to no more than 29.4 volts and during discharging to no less than 17.5 volts [25].

Figure 4.3: NEST's 25.2 volt, 6.7 amp-hour (168.8 watt-hour) custom lithium-ion battery. Figure reprinted from [25].

Specification	Value
Nominal Voltage	25.2 VDC
Charge Cut-off Voltage	29.4 VDC
Discharge Cut-off Voltage	17.5 VDC
Capacity	6.7 Ah (168.8 Wh)
Max Continuous Discharge Current	7 A
Cell Type	Lithium-Ion
Cell Form Factor	18650
# Cells	14
Cell Configuration	7 series, 2 parallel
Dimensions	135 x 48 x 74 mm
Weight	726 g

Table 4.8: Specifications of NEST's custom lithium-ion battery. Table adapted from [25].

The upper limit imposed by the PCM conforms to the maximum power source voltage requirement of 30 volts, but the PCM lower voltage limit is below the minimum voltage requirement of 22 volts. This was deemed acceptable because of the voltage-charge curve that lithium-ion batteries follow. The majority of a lithium-ion battery's discharge time is spent near the battery's nominal voltage until it quickly falls off as the battery approaches complete discharge. Therefore, although the battery has a discharge cutoff voltage below the minimum required voltage, the vast majority of the battery discharge is spent above the minimum required voltage. Furthermore, the excess battery capacity compensates for the small portion of discharge time spent below 22 volts.

4.4 Overcurrent Protection

Overcurrent protection was placed at key points in NEST's circuitry to protect against shorts and overloads. Replaceable fast-acting cartridge fuses were placed on the external power source connection, internal battery charging connection, internal battery discharging connection, DC converter inputs, and DC converter outputs. Figure 4.2 and Figure 4.4 show the portions of the single-line diagram containing overcurrent protection devices; a complete single-line diagram is contained in Appendix B. Table 4.9 lists a summary of fuse identifications, locations within the circuit, and ratings.

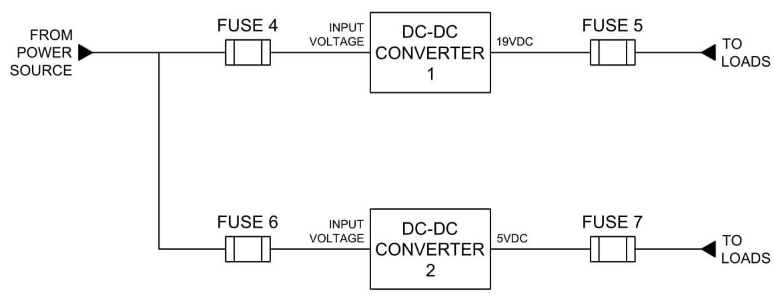

Figure 4.4: A portion of the single-line diagram showing overcurrent protection on the DC buck converters.

Fuse ID	Circuit Location	Fuse Rating
Fuse 1	External Power Connection	4 A
Fuse 2	Battery Input (Charging)	2 A
Fuse 3	Battery Output (Discharging)	4 A
Fuse 4	DC Converter #1 Input	3.5 A
Fuse 5	DC Converter #2 Input	3.5 A
Fuse 6	DC Converter #1 Output	2.5 A
Fuse 7	DC Converter #2 Output	3.5 A

Table 4.9: NEST's fuse schedule.

5. MECHANICAL DESIGN

NEST's mechanical design is well described as three distinct subassemblies that are mounted within a nearly-cubed-shaped, exoskeleton chassis. The first subassembly - the sensor array subassembly - contains NEST's sensors, sensor mounting adapters, and a common sensor mounting plate which arranges NEST's sensors into a robust and easily removable configuration. The second subassembly - the computer mounting subassembly - is simply the computer with an attached mounting adapter. Finally, the power electronics subassembly contains the battery, voltage converters, fuses, terminals, and wiring to connect these components to each other and NEST's loads. Details of the chassis and three subassemblies are discussed in Sections 5.1 - 5.4. Optional siding - addressed in Section 5.5 - attaches to the exterior of NEST to protect users from exposed, electrified terminals and to give NEST a clean, finished look. Figure 5.1 shows an isometric view of NEST without optional siding installed, while detailed mechanical drawings of NEST, its subassemblies, and all non-standard parts can be found in Appendix A; Table 5.1 lists a summary of specifications for the overall assembly.

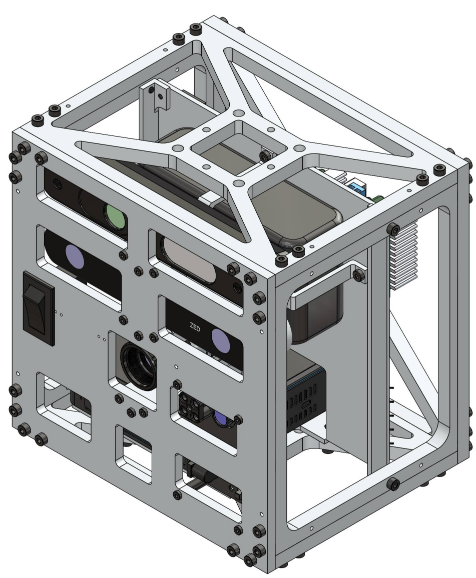

Figure 5.1: Isometric view of NEST without optional siding installed.

Specification	Value
Mass	∼6.4 kg (∼14.1 lbm)
Exterior Dimensions	21.8 cm (W) x 21.8 cm (L) x 17.3 cm (H)
Chassis Material	Aluminum
Siding Material	Acrylic Plastic
No. Mounting Points	3
Mounting Locations	(1) Top; (1) Back; (1) Bottom

Table 5.1: Select mechanical specifications of NEST.

5.1 Chassis

NEST's chassis is composed of five machined 3/8" 6061-T6 aluminum plates that are arranged in a 5-sided rectangular prism and fastened together with socket-head machine screws. The individual chassis parts have cutouts to reduce the overall weight of the chassis and contain various clearance and threaded holes for their fastening to each other and for the mounting of the subassemblies and optional siding panels. Additionally, the back chassis part has a cutout for the mounting of the three-way "Battery Charge/Disengage/Discharge" switch. Bolt patterns on the top, back,

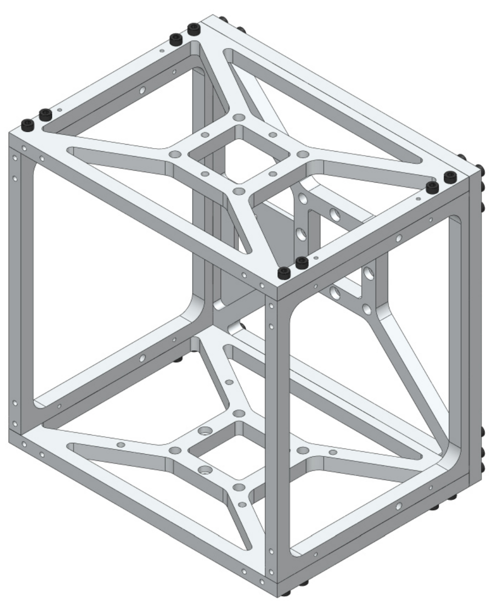

Figure 5.2: Isometric view of the chassis assembly.

and bottom chassis parts can be used to mount NEST to external structures and for the attachment of external assemblies to NEST; NEST may be mounted to external structures by any one of these sides, with the unused sides remaining free for the attachment of external assemblies. An isometric view of the chassis assembly is shown in Figure 5.2, while detailed mechanical drawings of the chassis assembly and individual chassis parts can be found in Appendix A.

No formal structural analysis was conducted during design of the chassis parts; instead, intuition and the fundamentals of material mechanics were leveraged while assessing the strength and stiffness of stock pieces of aluminum plate, and the chassis parts were intentionally over-engineered to guarantee rigidity of the chassis. Furthermore, redundant fasteners were used throughout the chassis assembly to guarantee adequate strength despite formal analysis. Since the over-engineered chassis conformed to the design requirements specified in Section 1.2, there was little motivation to reduce the weight of the chassis through optimization of the stiffness-to-weight-ratio via formal analysis, and over-engineering of the chassis was deemed an acceptable approach.

5.2 Sensor Array Subassembly

Multiple sensors may be utilized during any given application of NEST, and the correlation of sensor data first requires the calibration of the sensors with respect to each other. An important aspect of the sensor calibration is that it remains unchanged, since the need for frequent sensor recalibration undermines the time-saving and effort-saving nature of the NEST platform. The calibration of the sensors is dependent on their physical position and orientation with respect to each other and to the NEST chassis. Any disturbance in the position or orientation of a sensor will necessitate recalibration of that sensor. Therefore, it is critical that the spatial relationship between sensors remain constant throughout the operation of NEST.

To facilitate a constant spatial relationship between NEST's sensors and prevent the need for sensor recalibration, all five sensors were mounted to a single, common aluminum plate - shown in Figure 5.3; Figure 5.3 also shows the attachment of the ZED to the sensor mounting plate. The mounting of the sensors in this fashion isolates them from the other parts of NEST and allows for partial disassembly of NEST without requiring recalibration of the sensors.

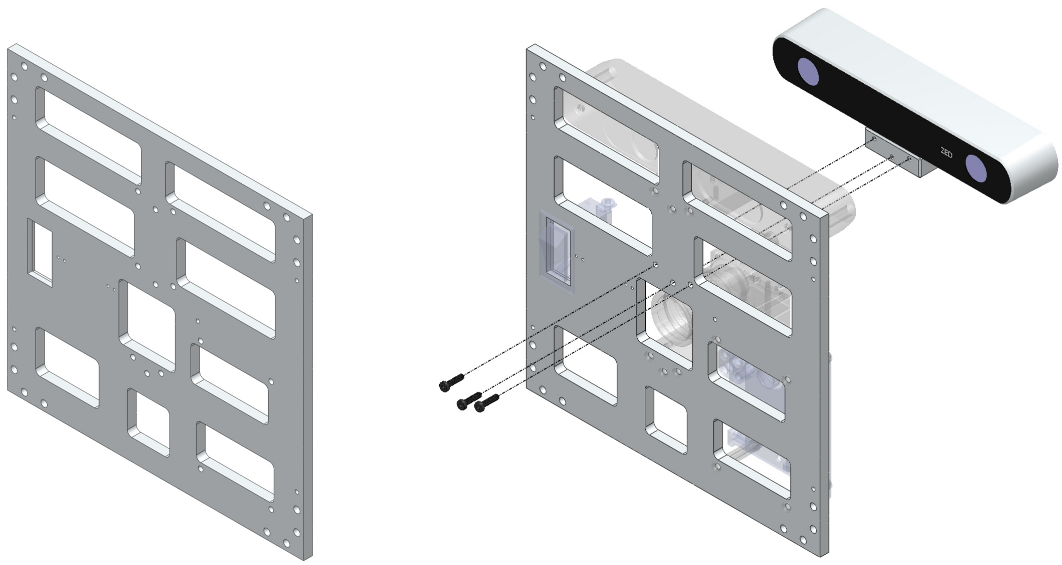

Figure 5.3: Isometric view of the sensor mounting plate (left); mounting of the ZED camera to the sensor mounting plate (right).

Figure 5.4: Isometric view of the sensor array subassembly (left); the sensor array subassembly mounted to the chassis with the chassis displayed transparent (right).

The entire sensor array can be removed from NEST without introducing disturbances in the relative positions and orientations of the sensors; only disassembly of the sensor array itself will require recalibration of the sensors. The VN-100 IMU and OPT8241-CDK-EVM LIDAR evaluation module are mounted directly to the sensor mounting plate, while mounting adapters were required for the attachment of the ZED, acA1300-200uc, and Xtion cameras. Figure 5.4 shows an isometric view of the sensory array subassembly; the same figure also shows the sensor array subassembly mounted to the chassis. Appendix A contains detailed mechanical drawings of the sensor mounting plate, attachment of each sensor, and the complete sensor array subassembly.

Disturbances in relative sensor positions and orientations can also be introduced by deflections of the sensor mounting plate under dynamic loading conditions. Therefore, it is critical that the sensor mounting plate be sufficiently stiff such that deflections of the sensor mounting plate due to dynamic loading are not a significant source of error in the spatial calibration of the sensors. As was the case with the design of the chassis, no formal analysis was conducted when the sensor mounting plate was designed; instead, the sensor mounting plate was intentionally over-engineered to ensure rigidity. The sensor mounting plate was formed from machined 1/4" 6061-T6 aluminum plate and is assumed to be stiff enough to preserve any sensor calibrations that are performed under static conditions.

5.3 Computer Mounting Subassembly

The mounting of the NUC computer required the use of a mounting adapter between the bottom chassis wall and the NUC's internally-threaded mounting holes. The mounting adapter was formed from 1/8" 6061-T6 aluminum plate with cutouts to reduce weight and clearance and threaded holes for its attachment to the NUC and chassis. Figure 5.5 shows an isometric view of the computer mounting subassembly, which is simply the NUC computer with attached mounting adapter; the same figure also displays the computer mounting subassembly mounted within the chassis. Appendix A contains detailed mechanical drawings of the computer mounting subassembly and all subcomponents.

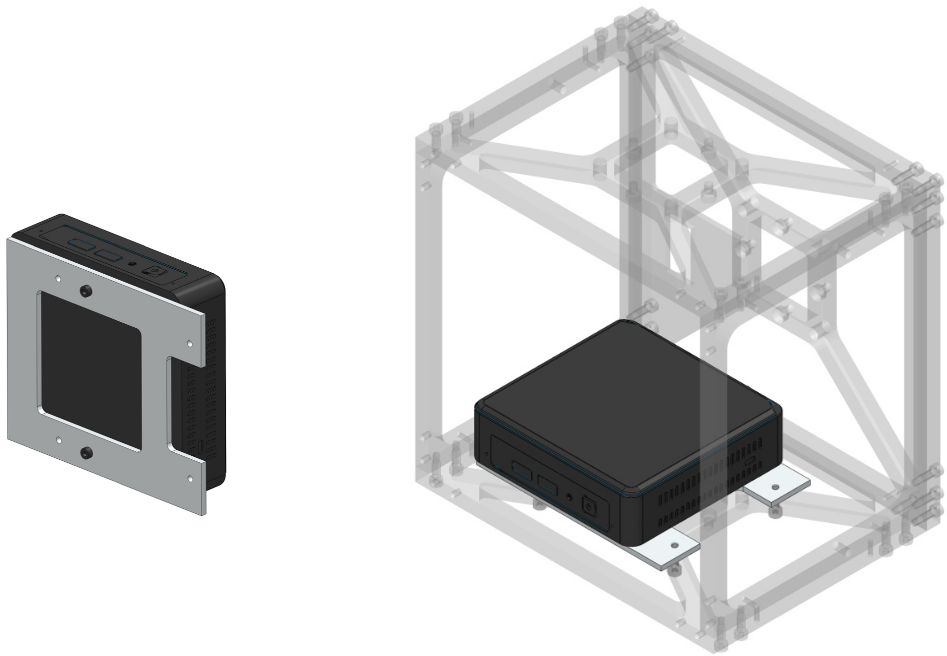

Figure 5.5: Isometric view of the computer mounting subassembly (left); the computer mounting subassembly mounted inside the chassis with the chassis displayed transparent (right).

5.4 Power Electronics Subassembly

The power electronics subassembly contains most of the electrical components necessary to facilitate the desired operation and safe powering of NEST. With the exceptions of the electrical loads and switches, all of NEST's electrical components are mounted to a common part - the power electronics plate - and are contained within the power electronics subassembly. This includes both DC step-down converters, all seven fuse holders, and both terminal blocks - all of which are permanently adhered to the top face of the power electronics plate with epoxy resin; the rechargeable battery is secured to the bottom face of the power electronics plate by two mounting brackets and socket-head screws. Wiring between components within the power electronics subassembly was completed using 18 AWG wire with soldered connections to the fuse holders and screw-terminal connections to the DC step-down converters and terminal blocks. Wiring connections between the power electronics subassembly and external power source, battery charger, NEST's loads, and externally mounted switches were made with nonpermanent, quick-disconnect connectors, which allows for the easy removal of the power electronics subassembly from NEST and switching of the power source without rewiring as mandated by the design criteria. Figure 5.6 shows isometric views of the power electronics subassembly (wiring not shown) as well as the power electronics subassembly mounted inside NEST's chassis; detailed mechanical drawings of the power electronics subassembly and its subcomponents can be found in Appendix A.

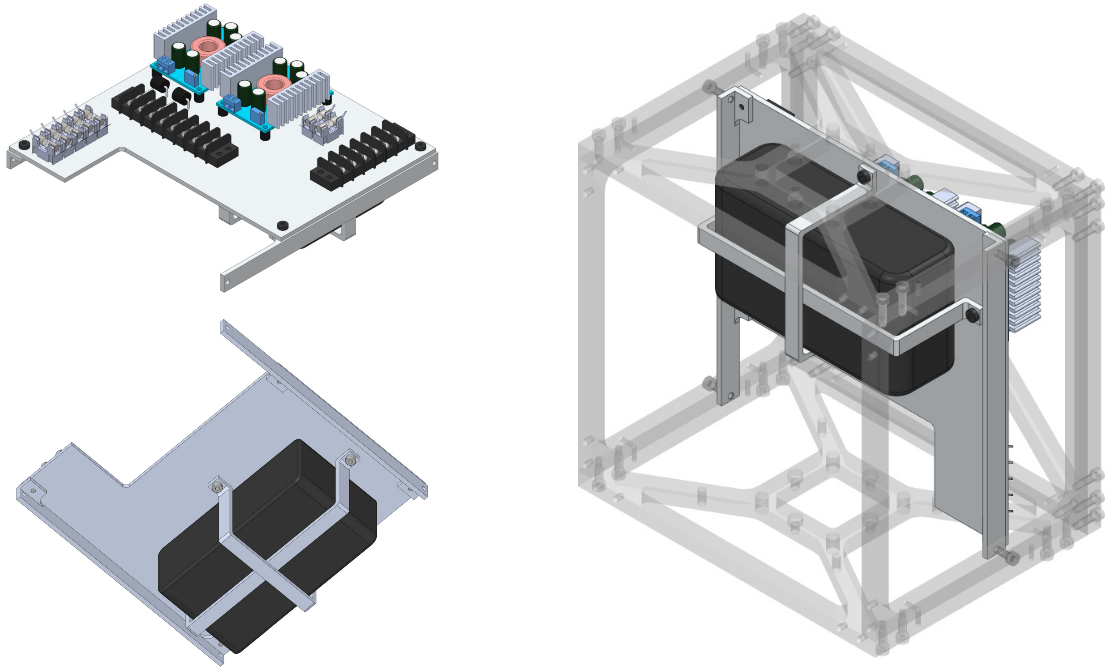

Figure 5.6: Isometric view of the power electronics subassembly (top left); alternate isometric view of the power electronics subassembly (bottom left); the power electronics subassembly mounted inside the chassis with the chassis displayed transparent (right).

The permanent attachment of components to the power electronics plate serves to discourage electrical modifications to the power electronics subassembly and is an attempt to protect NEST's computer and sensors from potential wiring errors that may be introduced as a result of modifying NEST. The attachment of the battery to the power electronics plate was made non-permanent so the battery may be easily replaced with an identical unit as its performance degrades with use. A thin layer of foam was added to the battery mounting brackets to ensure a distributed contact pressure along the length of the battery so as to prevent damage to individual battery cells and to prevent the battery from shifting during motion of NEST.

5.5 Siding

Optional siding panels were created for all six sides of NEST to shield users from bare electrical components and to give NEST a clean, finished look. The siding was formed from 1/8” opaque black acrylic plastic and each siding panel can be individually mounted directly to its respective chassis part. Cutouts were made in the top, back, and bottom siding pieces to allow for the mounting of NEST to exterior structures when the siding is installed using the chassis bolt patterns on the chassis walls. Cutouts were made in the front siding piece to prevent the siding from blocking the sensors’ fields-of-view. Additionally, a cooling fan was incorporated into the left siding piece and a vent cutout was made in the back siding piece to facilitate cooling of the interior electrical components when the siding is installed. Figure 5.7 shows NEST with and without the siding panels installed. Appendix A contains detailed mechanical drawings of the siding panels.

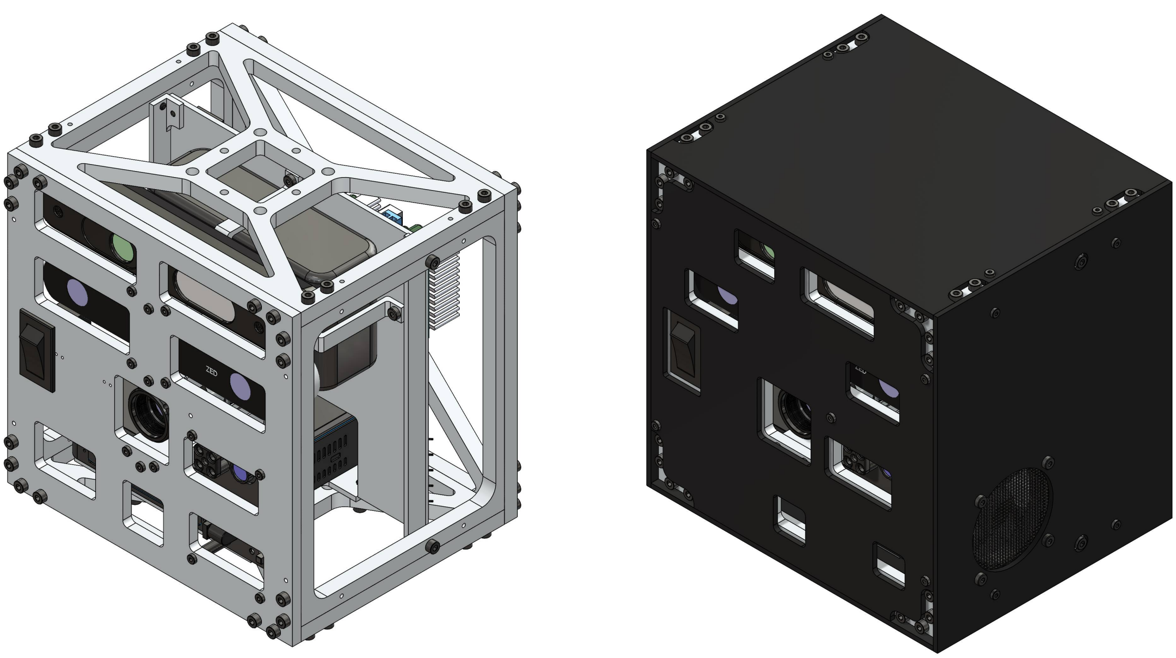

Figure 5.7: Isometric view of NEST without optional siding panels installed (left); isometric view of NEST with optional siding panels installed (right).

6. SOFTWARE

NEST's onboard computer will perform many computing tasks during typical usage of NEST. In addition to the algorithm-specific computations that will be carried out as part of the testing and validation of a particular algorithm, many ancillary tasks that support the testing of algorithms will be performed, which may include but are not limited to:

- The reception and execution of operational commands from remote, networked machines
- The establishment of connections to NEST's sensors
- The calibration of NEST's sensors
- The configuration of NEST's sensors to operate in specific modes
- The acquisition of raw sensor measurements
- The processing of raw sensor measurements to produce refined data
- The onboard storage of raw measurements and/or refined data
- The transmission of raw measurements and/or refined data to remote, networked machines
- The reception of refined data from remote, networked machines
- The storage of telemetry data from a truth-positioning system

The execution of these ancillary tasks requires substantial software resources, and the development of these resources is an ongoing task that will continue over the lifespan of NEST. Much computer code has already been developed for the execution of the listed ancillary tasks, and further code modifications and additions will continue to be made. At the time of this writing, all code operating on NEST has been written in C++, though Python will likely be incorporated in the future. In addition to the generation of original code to meet the specific needs of NEST, code written by the sensor manufacturers and the greater robotics community was leveraged. A detailed discussion of NEST's individual software modules is not included in this document due to length and scope considerations, but code examples have been included to give readers some insight into NEST's software. Appendix C contains simple code examples for the acquisition and recording of measurements from the VN-100 IMU and images from the ZED camera. Section 6.1 briefly discusses NEST's operating system.

To ease the burden of developing NEST's software, Robot Operating System (ROS) was deployed on NEST. ROS is an open-source framework for developing robotic platforms, and its incorporation into NEST simplified NEST's deployment as part of a multiple-machine laboratory configuration and allowed community-developed code to be more easily leveraged. The reader is encouraged to independently investigate the merits of ROS since its capabilities are too extensive to be adequately addressed in this document, though Section 6.2 provides some insight into the benefits of using such a framework.

6.1 Operating System

Linux Ubuntu 16.04 LTS (Xenial Xerus) was chosen for NEST's operating system because of its familiarity to LASR researchers and for consistency of operating systems between machines when operating NEST in a multi-machine configuration at LASR; Linux Ubuntu is the primary operating system utilized within LASR and is currently implemented on many of LASR's machines. Ubuntu distribution 16.04 was chosen primarily for its compatibility with ROS Kinetic, and for the longevity provided by the 16.04 distribution release cycle. The 16.04 distribution of Ubuntu has an official end-of-life of April 2021 with extended security maintenance through April 2024 [26]. NEST's operating system may be upgraded to future Ubuntu distributions as NEST outlives the product cycle of distribution 16.04.

6.2 Benefits of Deploying Robot Operating System

Robot Operating System (ROS) was deployed on NEST to ease the burden of developing NEST's software. ROS is a framework for writing robot software; it is a collection of tools, libraries, and conventions that help to simplify the development of robotic platforms [27]. Unlike the name may suggest, ROS does not replace the host machine's operating system; NEST simultaneously runs Ubuntu and ROS, and ROS acts as middleware to manage ROS-enabled applications running on ROS-deployed machines. This gives NEST users the flexibility to utilize ROS when it is convenient without requiring users to incorporate ROS into all aspects of their computing.

One benefit of utilizing ROS on NEST is the flexibility to trivially extend the operation of NEST from a stand-alone machine configuration to operating NEST as part of a multiple-machine network without the need to write additional software. To demonstrate this principle, the recording of an image stream from a single camera is considered. In a non-ROS implementation, a single program would be executed to establish a connection to the camera, continually acquire images, and write the images to files. Figure 6.1 depicts this single-executable, single-machine architecture.

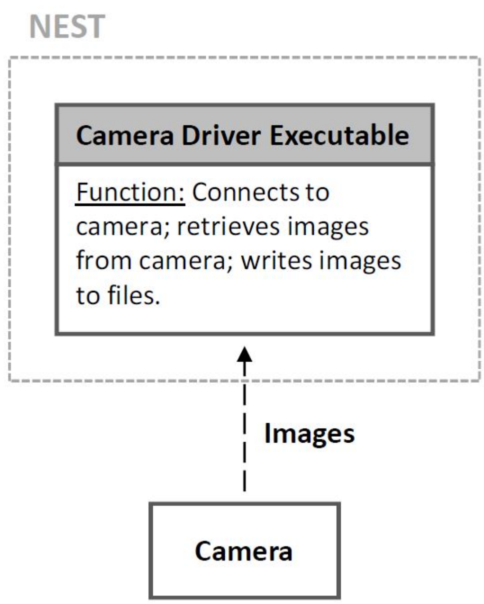

Figure 6.1: A software diagram showing a basic image stream implemented using one executable program on a single machine.

With a ROS implementation of the same image stream, the functionality of the sole executable of the non-ROS implementation is appropriately split into two distinct executable programs, and a ROS virtual communication bus is established to facilitate the transmission of images between the executables. The first of the two executables - the “image capture” program - establishes a connection to the camera, continually acquires images, and continually broadcasts the images over ROS’s virtual communication bus. The second of the two executables - the “image recorder” program - receives images published on the ROS virtual communication bus and writes the received images to files. Figure 6.2 depicts the multiple-executable, single-machine ROS implementation of the same image stream shown in Figure 6.1.

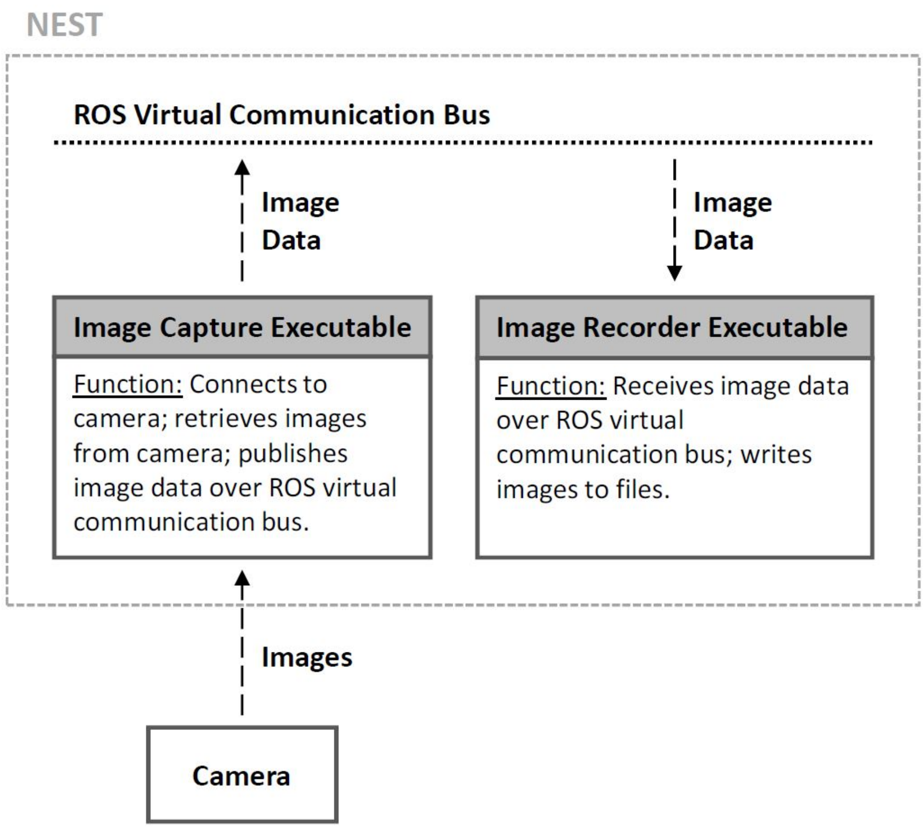

Figure 6.2: A software diagram showing a basic image stream implemented using ROS and two executable programs on a single machine.

From the user's perspective, the software architectures depicted in Figure 6.1 and Figure 6.2 provide the same overall functionality: an image stream from a camera is displayed on-screen, and a single machine is utilized to accomplish this task. Since the ROS virtual communication bus is trivially extended from a single machine to additional, networked machines, the advantage provided by splitting the image recording functionality into separate executables is clearly demonstrated by running the "image capture" and "image recorder" executables on separate machines. In a multiple-machine configuration, the first machine (NEST) runs the “image capture” program to acquire and transmit images, while a second, remote machine runs the “image recorder” program to receive the image stream and write the images to files. Since ROS manages the transmission of images between the individual executables running on separate machines in the same way it does between the individual executables running on the same machine, the same “image recorder” program can be leveraged on NEST and remote machines. This provides the flexibility to record images onboard NEST, on a remote machine, or both simultaneously without requiring the development of additional software. Figure 6.3 shows this multiple-executable, multiple-machine image stream implementation using ROS.

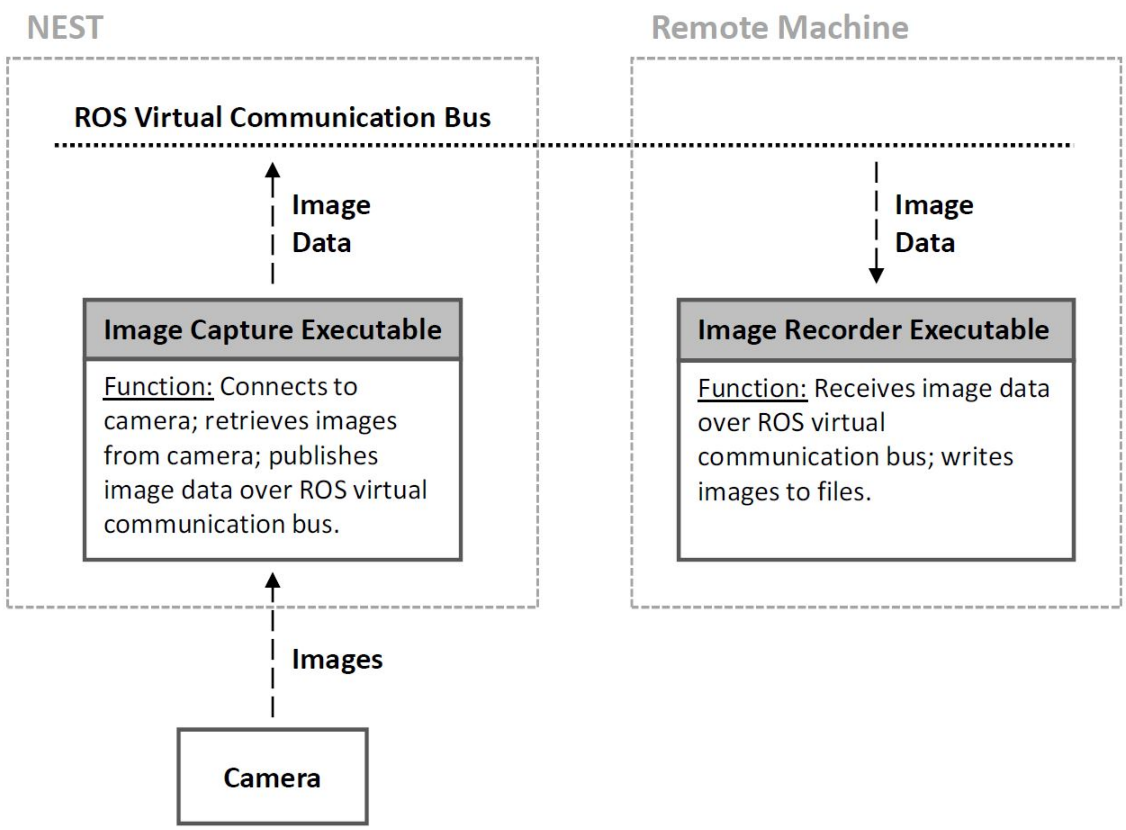

Figure 6.3: A software diagram showing the remote broadcast of a image stream across two machines using ROS.

Generalizing and extending this principle, individual software modules can be written for distinct scopes of functionality - such as the acquisition of raw measurement data from a sensor, the processing of measurement data to produce robot motion commands, the recording of data, or the display of data - and can be executed entirely onboard NEST or partially onboard NEST and partially on separate, networked machines. This give researchers the flexibility to operate NEST as a self-contained platform or as part of a larger network without requiring additional software development to extend NEST's functionality.

Another benefit of utilizing ROS on NEST is the ability to leverage open-source ROS codes written by the greater robotics community. At the time of this writing, over 3,000 open-source software packages exist in the ROS ecosystem, with functionality ranging from basic sensor drivers to proof-of-concept implementations of new algorithms. Contributions to ROS packages and some 22,000 wiki pages are made by a community of over 3,300 that stretches world-wide, with most users residing in research labs. The modularity of ROS allows users to pick and choose which portions of their project leverage the community's expertise and which functionality they write themselves [28].

A new distribution of ROS is released every calendar year and is targeted at a specific distribution of Linux Ubuntu. ROS distributions are often supported for multiple, overlapping years, so there may be multiple actively supported distributions at any point in time. At the time of NEST development, actively maintained and supported ROS distributions included Indigo, Kinetic, Lunar, and Melodic [29]. While ROS Indigo - targeted at Ubuntu 14.04 [30] - and Ubuntu 14.04 are compatible with the APIs of NEST's sensors, Indigo's April 2019 planned end-of-life did not allow for longevity of the final system. The planned end-of-life for Lunar and Melodic were more distant than Kinetic [29], but Lunar and Melodic are not compatible with all of NEST's sensors' APIs. Therefore, ROS Kinetic was chosen for NEST due to its compatibility with NEST's operating system and sensors, and its facilitation of system longevity. NEST's ROS distribution may be upgraded as needed over the lifespan of NEST.

7. TYPICAL LABORATORY UTILIZATION

NEST may be utilized in the laboratory in a variety of ways. The manner in which NEST is utilized can be characterized in two ways: the operational role NEST plays in the laboratory, and the implementation configuration in which NEST carries out its operational role. It is the numerous combinations of operational roles and implementation configurations that gives NEST great utility, and the potential realizations of these two characterizations are discussed in the following sections.

7.1 Operational Roles

Preconfigured Desktop Computer

Operating in its most basic role, NEST can serve as a preconfigured desktop machine - with sensors already physically connected to the computer and all necessary software installed and configured - immediately ready to operate sensors, acquire measurements, process data, and run research algorithms. Where researchers might otherwise spend time and effort configuring another machine for development during the preliminary stages in a project, NEST's ability to be operated as a stand-alone computer allows researchers to save time by developing directly onboard NEST at their workstation. The capabilities of the NUC afford users of NEST the flexibility to operate the platform as they would any other desktop machine. Users may directly connect a monitor through the NUC's HDMI port, and with the use of a USB hub connected to the NUC's single unused USB port, connect a keyboard, mouse, and portable USB drive; Figure 7.1 depicts such a setup. The likeness of NEST to a desktop computer is furthered by NEST's ability to receive power indefinitely from an external power source and connect to a network through either a wired or wireless connection. Finally, the operating system - Linux Ubuntu 16.04 - provides users with the full computing functionality of a traditional desktop machine.

Figure 7.1: Conceptual illustration of NEST utilized as a desktop computer with a monitor, keyboard, and mouse.

Mobile Sensing Platform

NEST is more than simply a preconfigured computer. Similar to the value provided by a laptop computer due to its mobility when compared against a desktop computer, the value of NEST is best seen in its operation as a mobile platform. NEST's compact size, internal power capabilities, and wireless networking capabilities allow for mobile operation without the need for tethering cabling. This means NEST can be mounted to a motion-providing robot or manually manipulated while serving as a mobile sensing platform - collecting and storing sensor measurements onboard, or transmitting telemetry to remote machines over a network.

Vehicle Emulator

Building on NEST's capability to act as a mobile sensing platform, NEST's significant processing power allows the acquired sensor measurements to be processed directly onboard to produce meaningful outputs. The result is the ability for NEST to serve not only as a data collection platform, but also to emulate the operation of a vehicle.

7.2 Implementation Configurations

NEST as a Stand-Alone Machine

The simplest implementation configuration through which NEST may be utilized is as a stand-alone machine. The unconventional exterior appearance of NEST disguises the capabilities of the powerful computer housed within; the NUC is a relatively powerful computer originally intended for use by consumers as a desktop machine replacement. Due to the significant onboard processing power, NEST is not only capable of operating sensors and collecting measurements, but also of processing data directly onboard without the use of additional machines.

NEST with One Additional Machine

A more common implementation configuration is that of NEST networked with a single additional machine - hereafter referred to as the "ground station". Through the ground station, researchers may remotely issue commands to NEST, receive data from NEST, and transmit data to NEST without having to physically connecting to it. The benefit of such a configuration is the flexibility to move NEST freely throughout the laboratory space, since it is no longer tied to a monitor, keyboard, and mouse. This configuration can be implemented in two possible variations. In the first variation of this configuration, NEST acts as a self-contained vehicle emulation platform and may perform any or all of the following tasks:

- sensor measurement acquisition
- execution of research algorithms
- onboard recording of raw sensor measurements and/or research algorithm outputs
- transmission of raw sensor measurements and/or research algorithm outputs

In this same implementation configuration, the ground station is used only for experimental oversight and control. In this high-level oversight role, the ground station may perform any or all of the following tasks:

- initiation of the experimental run, i.e. initiation of NEST data collection and processing

- real-time display and/or recording of the raw sensor measurements acquired by NEST
- real-time display and/or recording of the outputs of the algorithms running on NEST
- open-loop/closed-loop control of any motion-providing robot to which NEST may be mounted

The second variation of this configuration has NEST sharing some of the computational load with the ground station. In this second variation, NEST transmits raw and/or preprocessed measurement data to the ground station for further processing, and research algorithms are run on either NEST, the ground station, or both machines. NEST may perform any or all of the following tasks in this second variation:

- sensor measurement acquisition
- preprocessing of sensor measurements
- onboard recording of raw/preprocessed measurement data
- transmission of raw/preprocessed measurement data over the network
- execution of research algorithms
- transmission of research algorithm outputs over the network

In this same variation - where the ground station supplements NEST's processing capabilities - the ground station may perform any or all of the following tasks:

- initiation of the experimental run, i.e. initiation of NEST data collection and processing
- execution of research algorithms
- real-time display and/or recording of the raw sensor measurements acquired by NEST
- real-time display and/or recording of the outputs of the algorithms running on NEST
- real-time display and/or recording of the outputs of the algorithms running on the ground station
- open-loop/closed-loop control of any motion-providing robot to which NEST may be mounted

NEST with Multiple Additional Machines

Other possible implementation configurations consist of NEST networked with multiple additional machines. Such configurations are similar to that of NEST networked with one additional machine, but computational tasks may be distributed as needed across any of the machines in the configuration. An example of one possible configuration involving multiple additional machines is the use of a ground station computer for high-level experimental oversight (i.e. command and control), a separate computer to act as a motion controller for a motion-providing robot, NEST as a vehicle emulator, and an additional computer for the real-time display of simulation graphics and outputs. Such an implementation is illustrated in Figure 7.2.

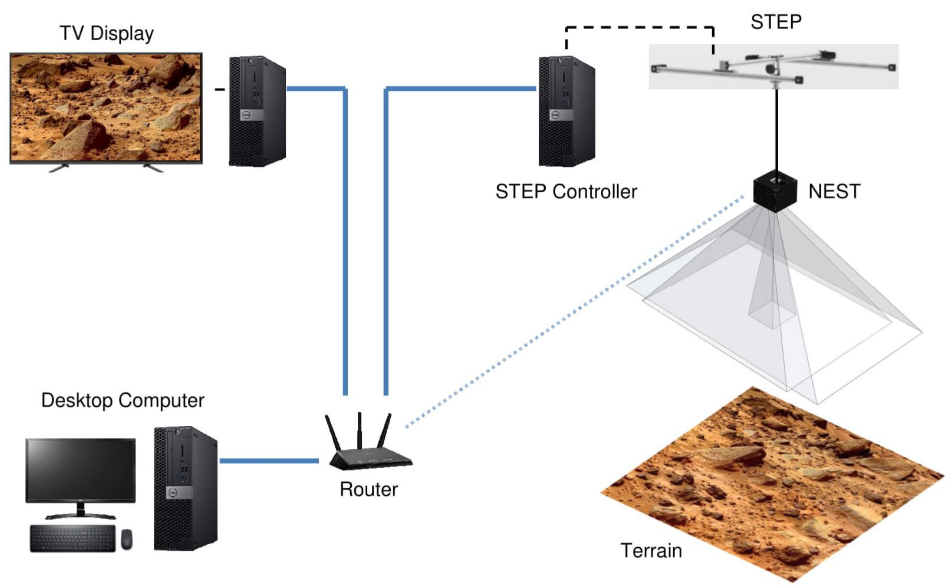

Figure 7.2: An example laboratory setup involving NEST and multiple additional machines.

8. SUMMARY

A new robotic platform - the Navigation, Estimation, and Sensing Testbed (NEST) - was developed for Texas A&M's Land, Air, and Space Robotics Laboratory. NEST supports algorithm research by serving as a preconfigured vehicle emulation and sensing platform to facilitate hardware-in-the-loop simulations for the testing and validation of new algorithms. With its broad sensing capability and mature electrical, mechanical, and software infrastructure, NEST reduces the entry cost of conducting future research by minimizing future overhead development. NEST can be immediately applied to a range of applications while requiring minimal, if any, additional development before deployment. NEST can be used as a stand-alone platform, or be seamlessly integrated into a larger network of machines in the laboratory.

8.1 Future Work

It is anticipated that modifications and additions to the NEST platform will continue to be made over the lifespan of NEST. General software developments are expected to be a continuous effort; such developments include those related to the networking of NEST with additional machines, the remote command and control of NEST from networked machines, and the transmission and storage of data onboard NEST. Software resources for the acquisition of measurements from existing sensors have been developed to a basic state, but will be further developed to give researchers more options regarding data collection. Additionally, periodic hardware and software modifications and additions will be made as needed to accommodate additional or alternative sensors. Less frequent changes include upgrading NEST's computer and transitioning NEST's operating system and ROS versions to newer distributions.

LASR researchers are currently exploring the addition of an alternate LIDAR sensor. Should the sensor be selected for incorporation into NEST, a mounting adapter and sensor driver will be developed to accommodate the new sensor; similar changes may be made in the future as NEST's sensor suite is modified with additional or alternate sensors.

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APPENDIX A

MECHANICAL DRAWINGS

Contents

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10100	CHASSIS ASSEMBLY	1
2	10712	SPDT ROCKER SWITCH	1
3	10400	SENSOR ARRAY	1
4	10943	M4x0.7 - 6H 14MM SOCKET HEAD SCREW	24
5	10200	POWER ELECTRONICS ASSEMBLY	1
6	10300	NUC COMPUTER MOUNTING ASSEMBLY	1
7	10511	SIDING FRONT	1
8	10894	0.25IN OD 3/32 IN ALUMINUM SPACER	5
9	10932	M3x0.5 - 6H 8MM LOW PROFILE SOCKET HEAD SCREW	25
10	10541	SIDING BOTTOM	1
11	10550	SIDING LEFT ASSEMBLY	1
12	10561	SIDING RIGHT	1
13	10520	SIDING BACK ASSEMBLY	1
14	10531	SIDING TOP	1

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

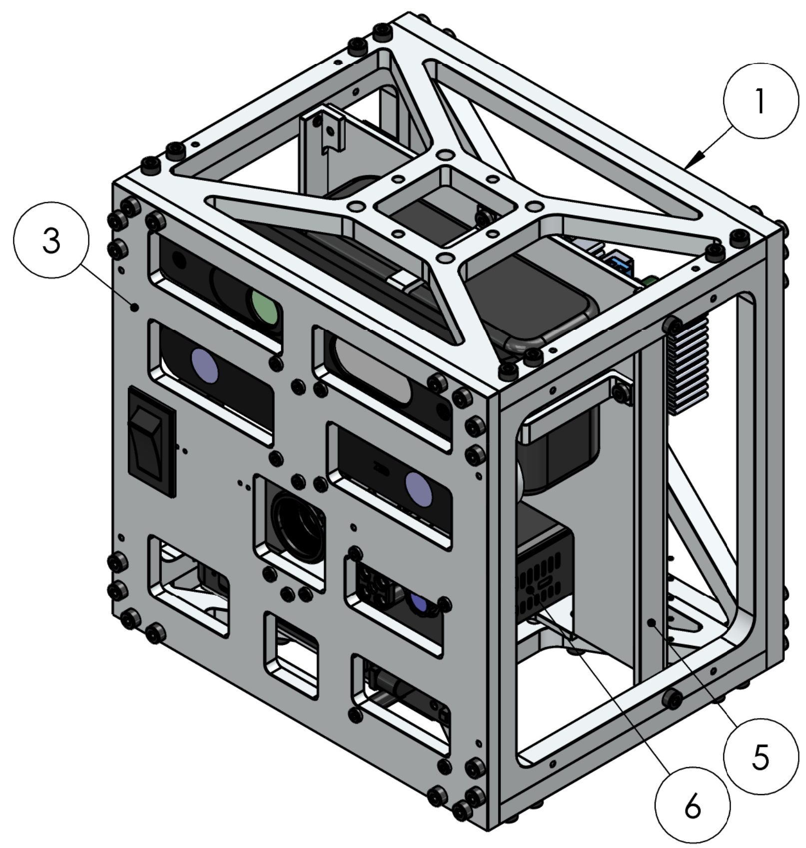
COMMENTS:

MATERIAL:

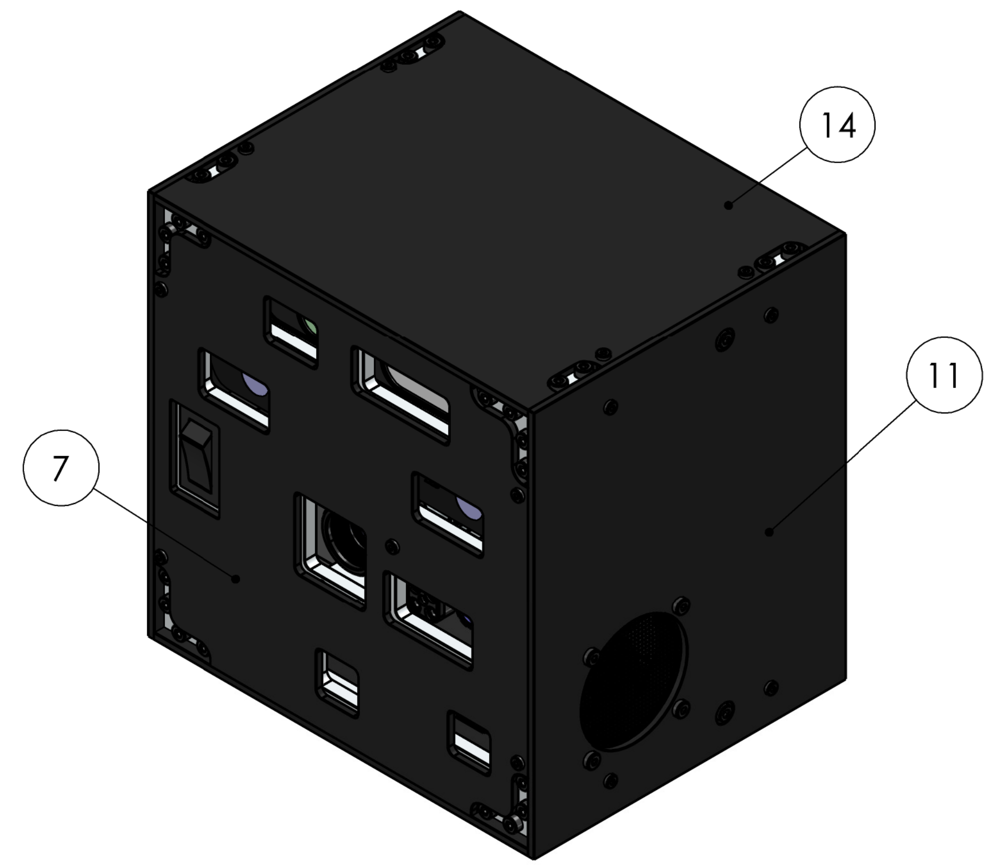
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NEST**

PROJECT:	DWG NO.:		REV:
NEST	10000		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 1 OF 14



ISOMETRIC VIEW - WITHOUT SIDING



ISOMETRIC VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

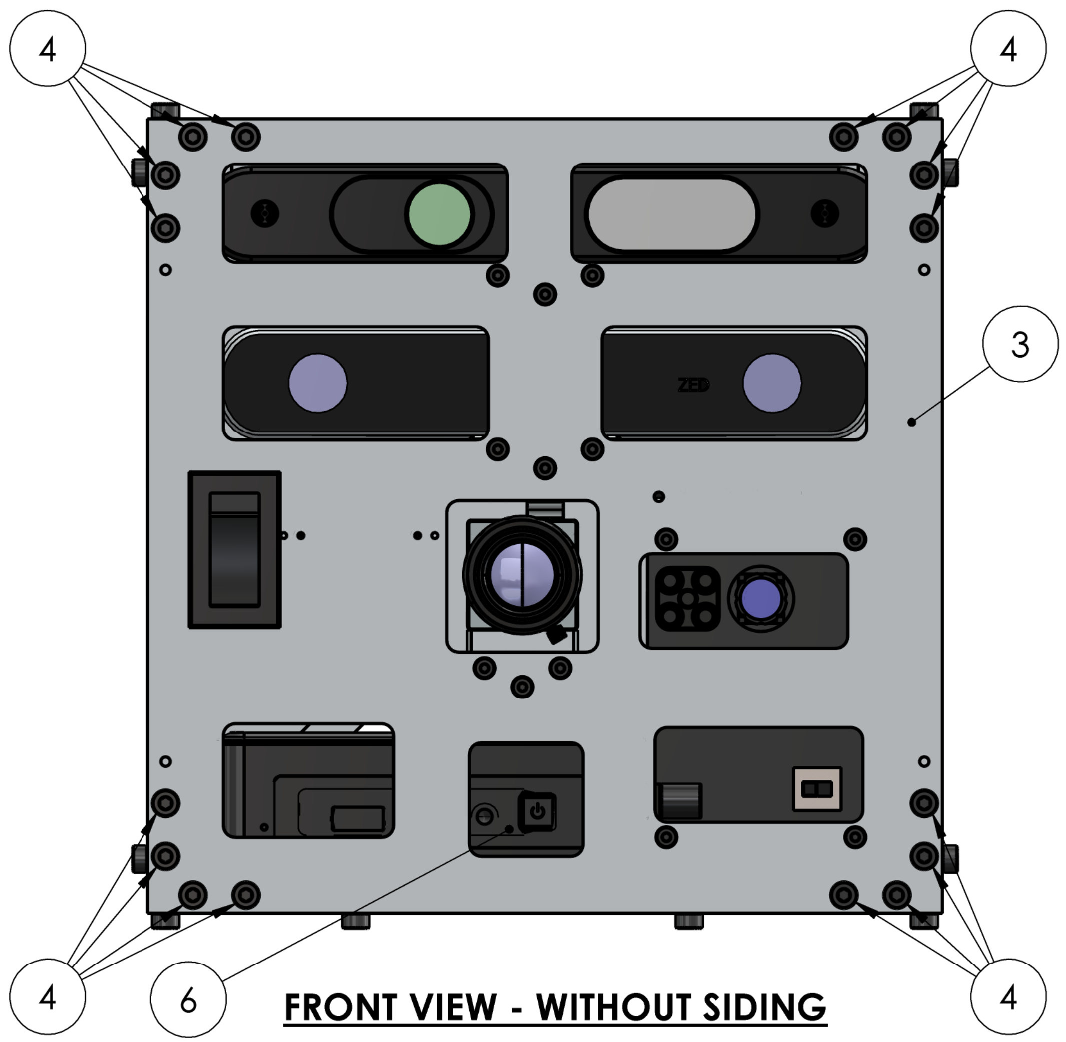
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

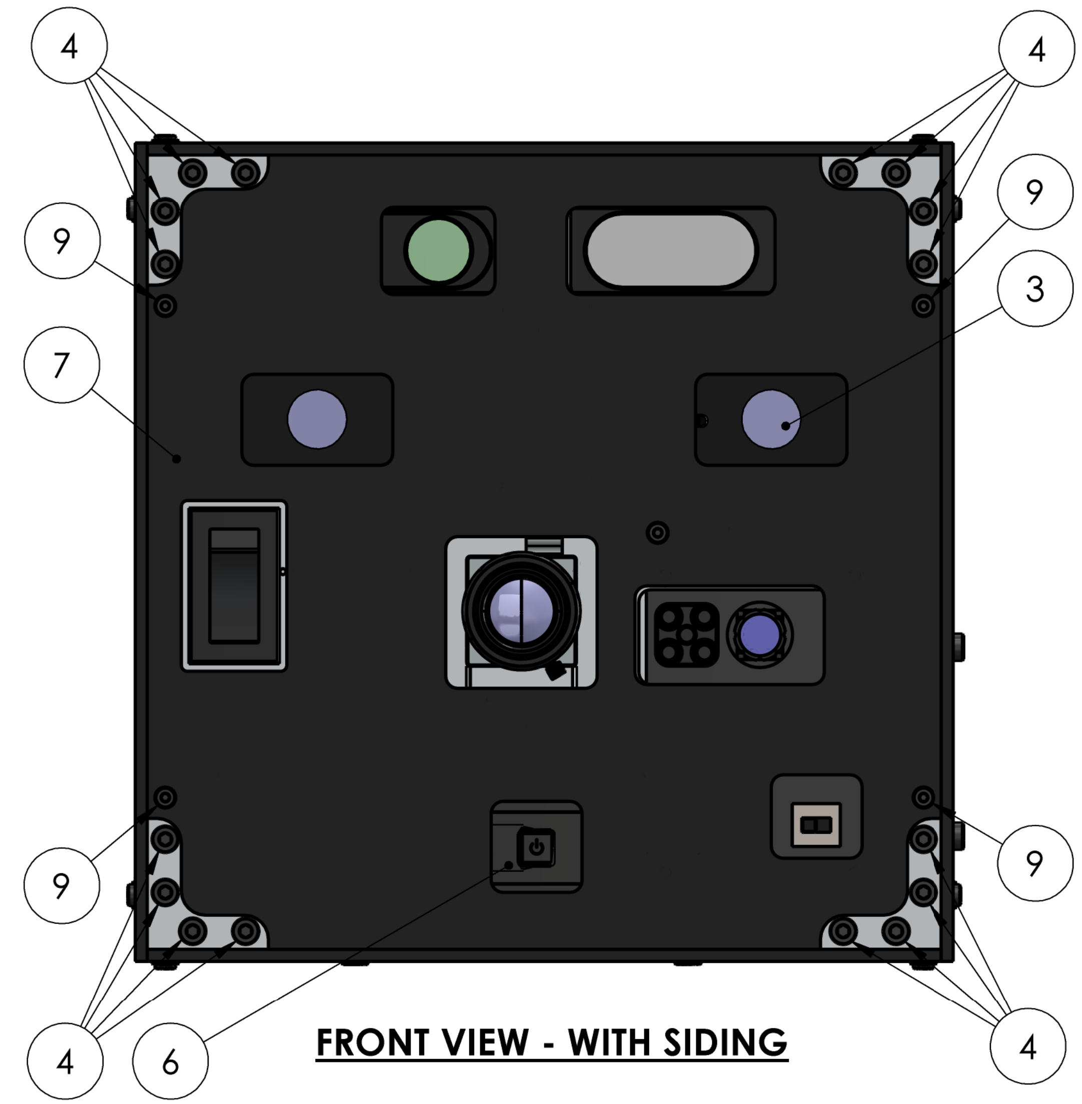
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:3	SHEET: 2 OF 14



FRONT VIEW - WITHOUT SIDING



FRONT VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

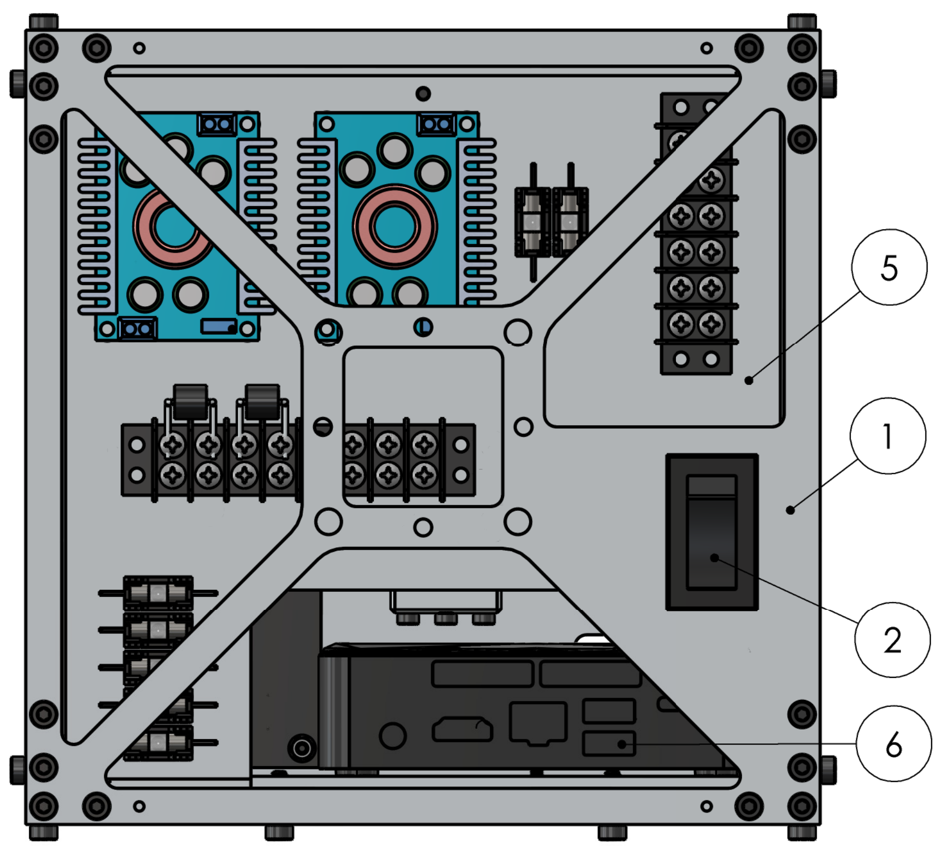
MATERIAL:

LASR

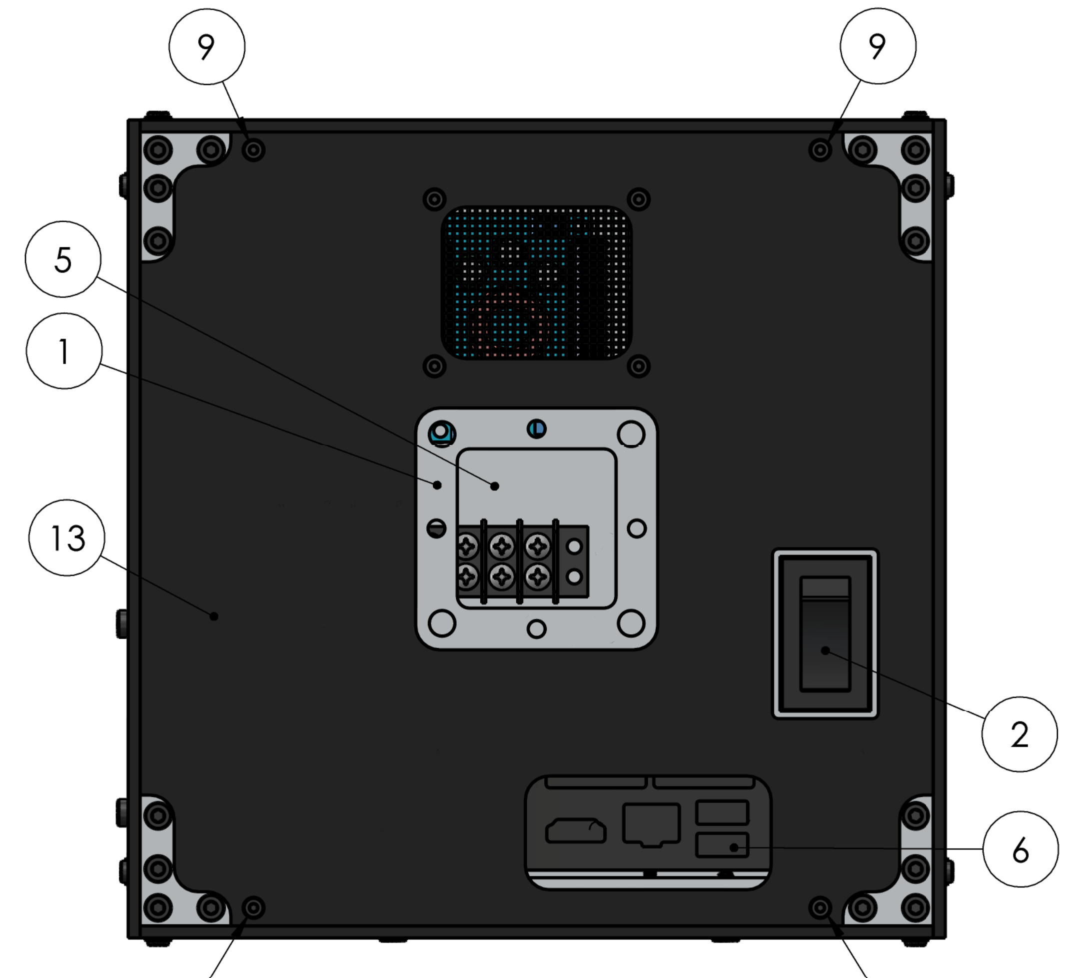
LAND, AIR, AND SPACE ROBOTICS LABORATORY

TEXAS A&M UNIVERSITY

TITLE: NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 3 OF 14



BACK VIEW - WITHOUT SIDING



BACK VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

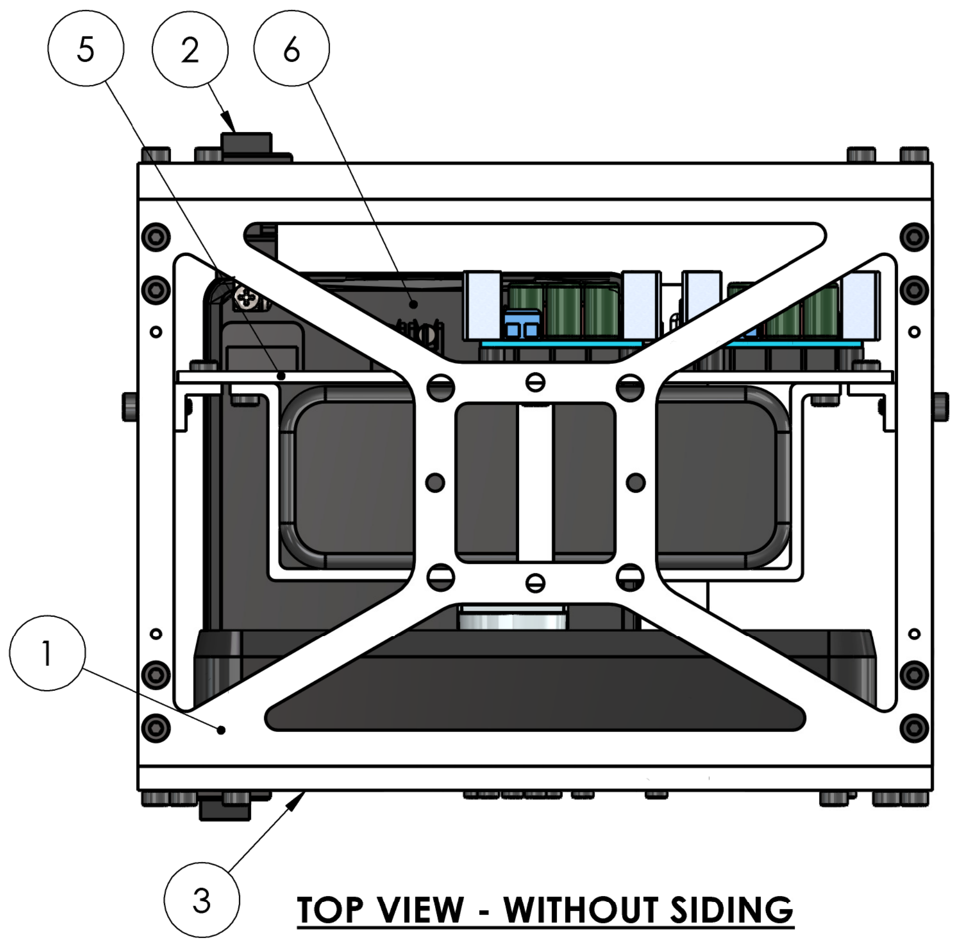
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

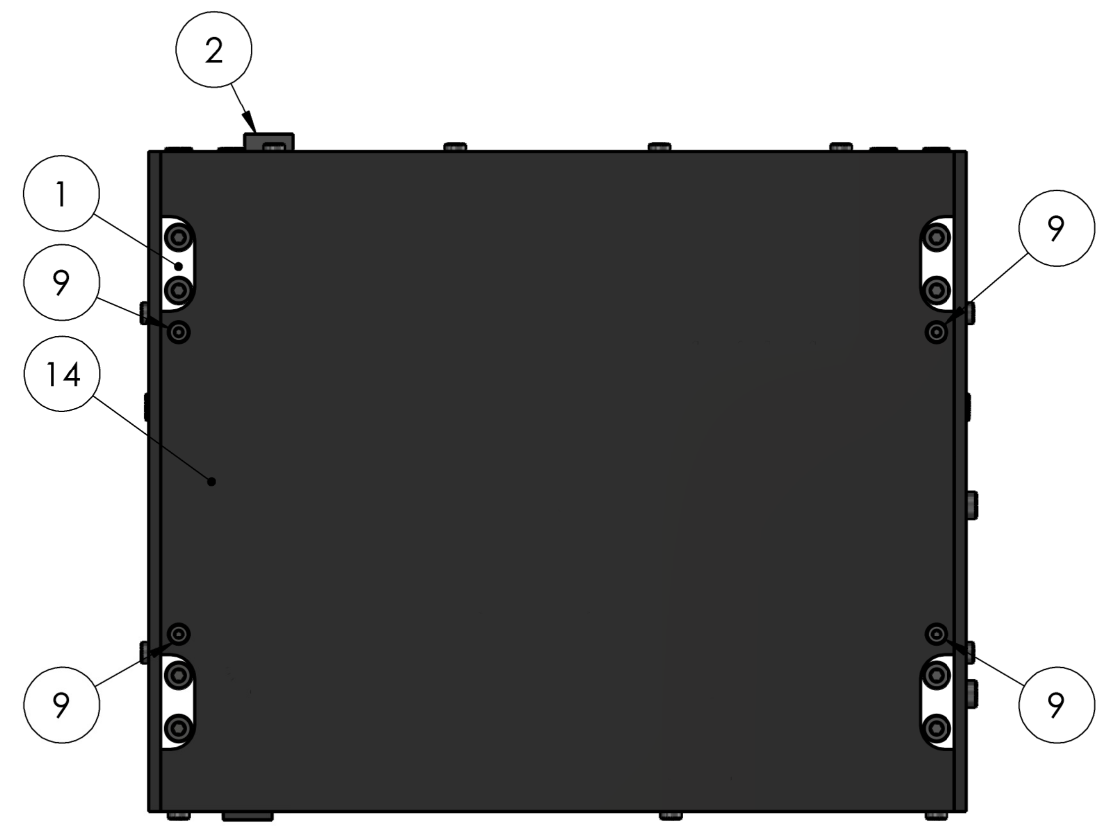
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 4 OF 14



TOP VIEW - WITHOUT SIDING



TOP VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

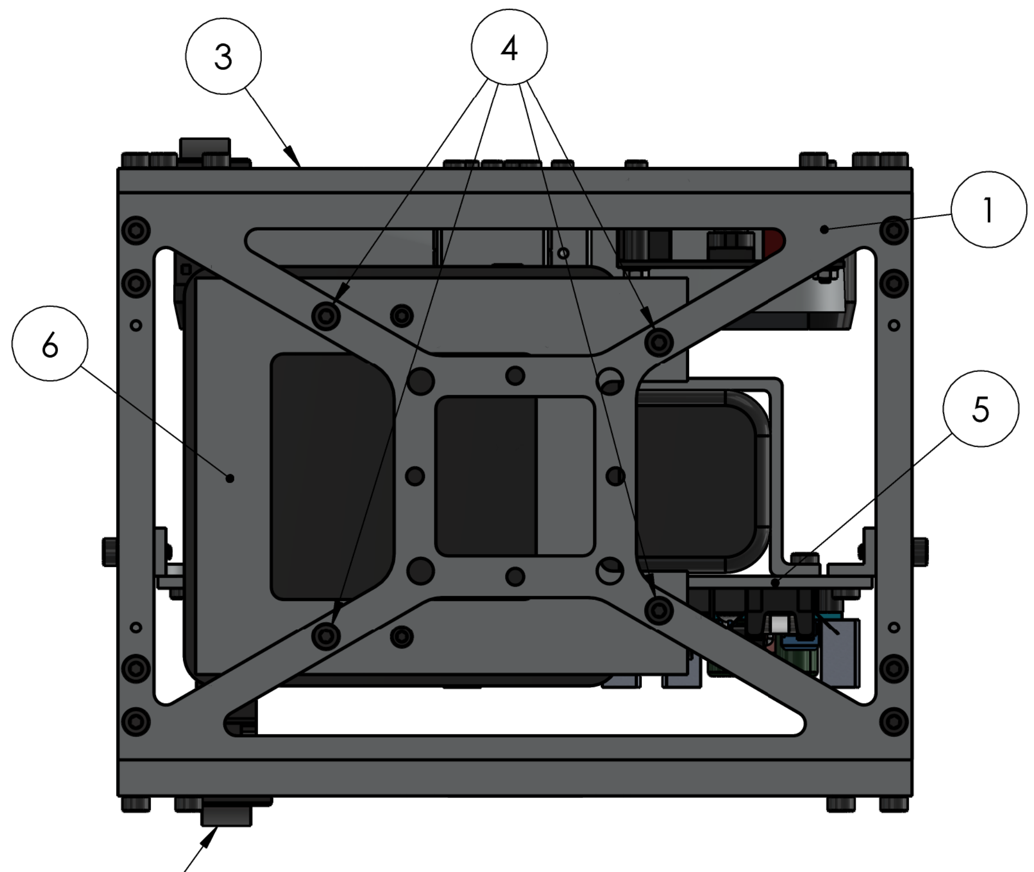
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

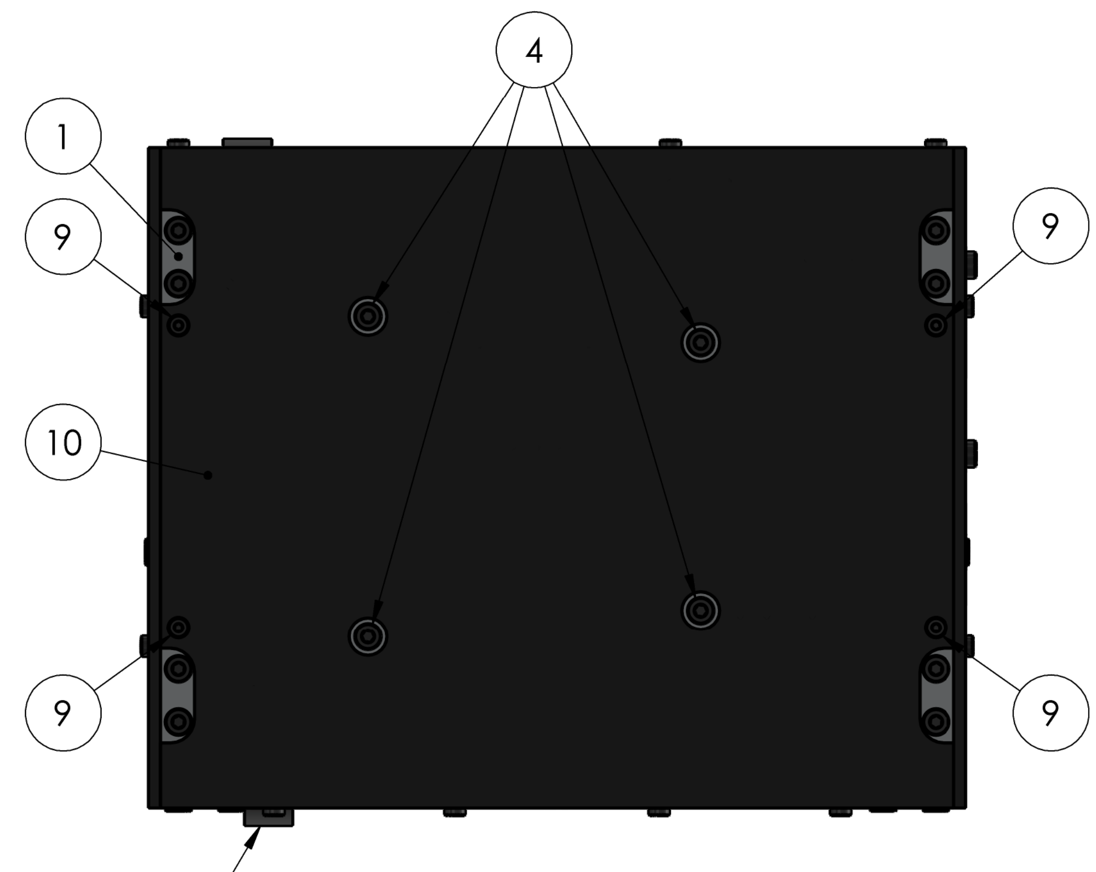
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 5 OF 14



BOTTOM VIEW - WITHOUT SIDING



BOTTOM VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

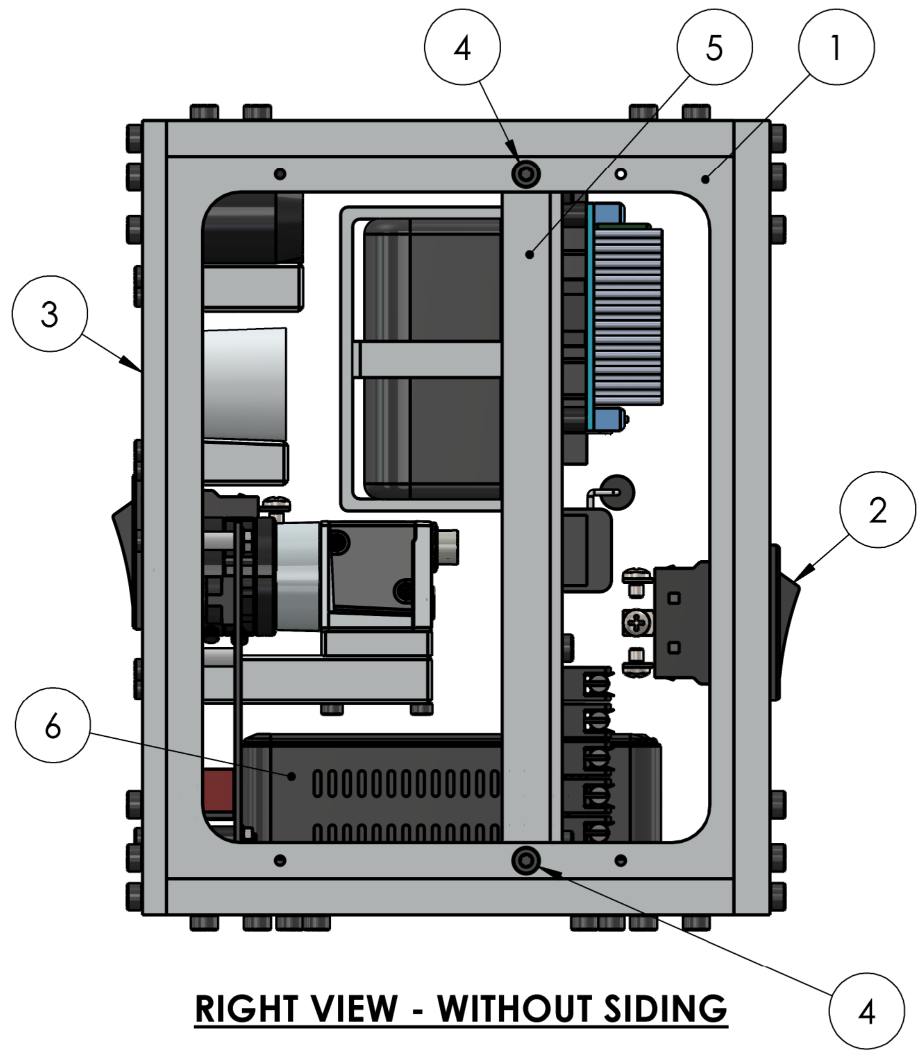
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

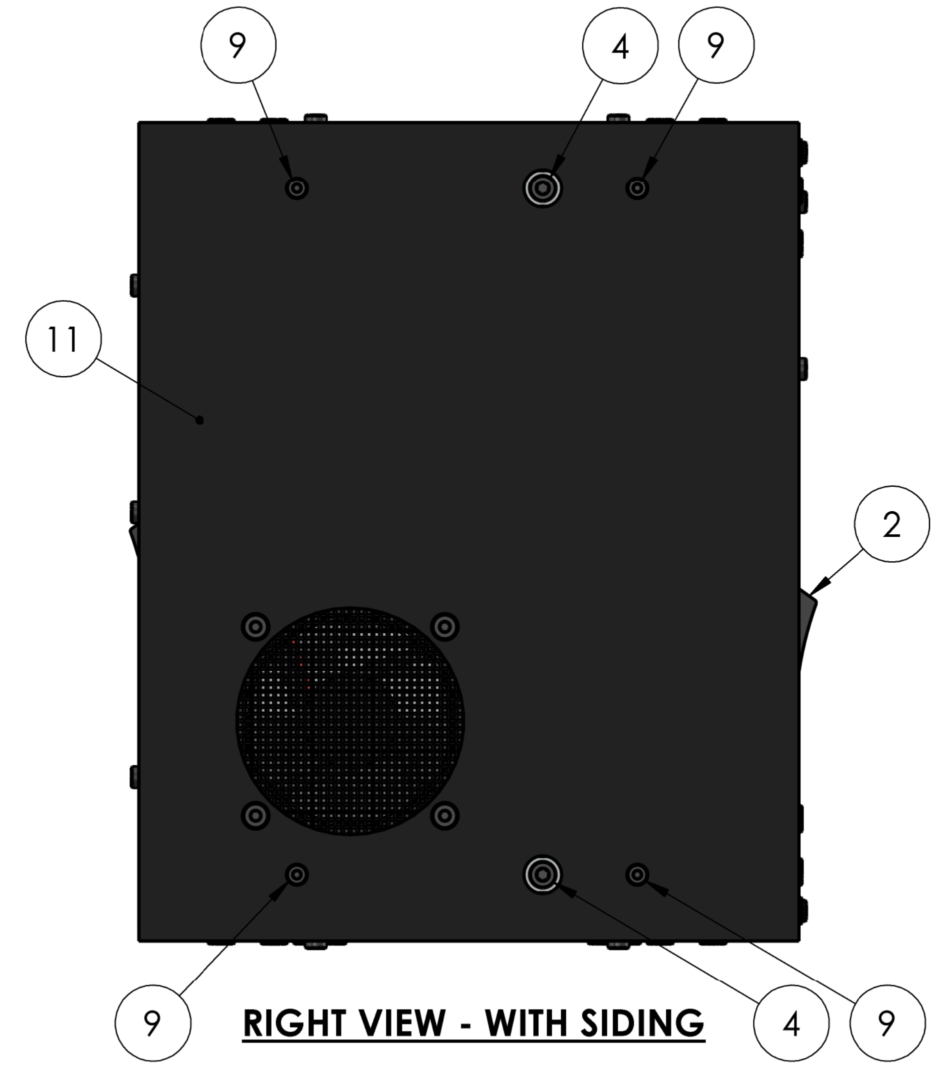
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:			
NEST			
PROJECT: NEST	DWG NO.: **10000**		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 6 OF 14



RIGHT VIEW - WITHOUT SIDING



RIGHT VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

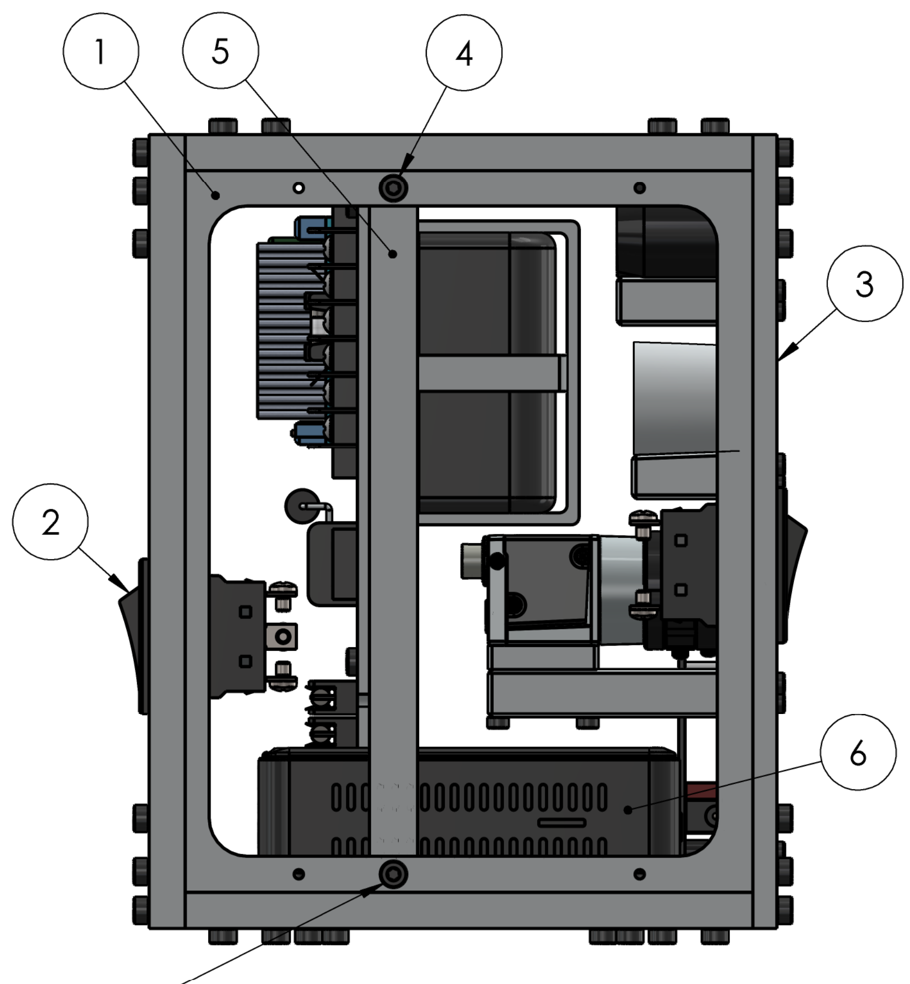
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

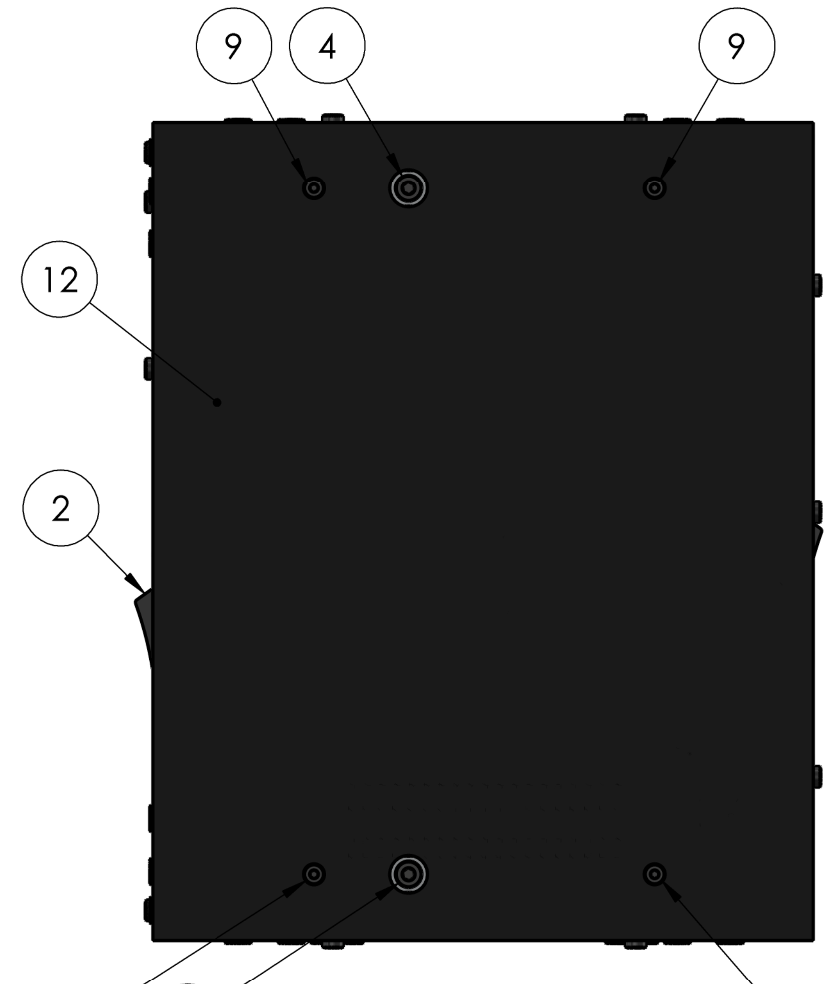
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:			
NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 7 OF 14



LEFT VIEW - WITHOUT SIDING



LEFT VIEW - WITH SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

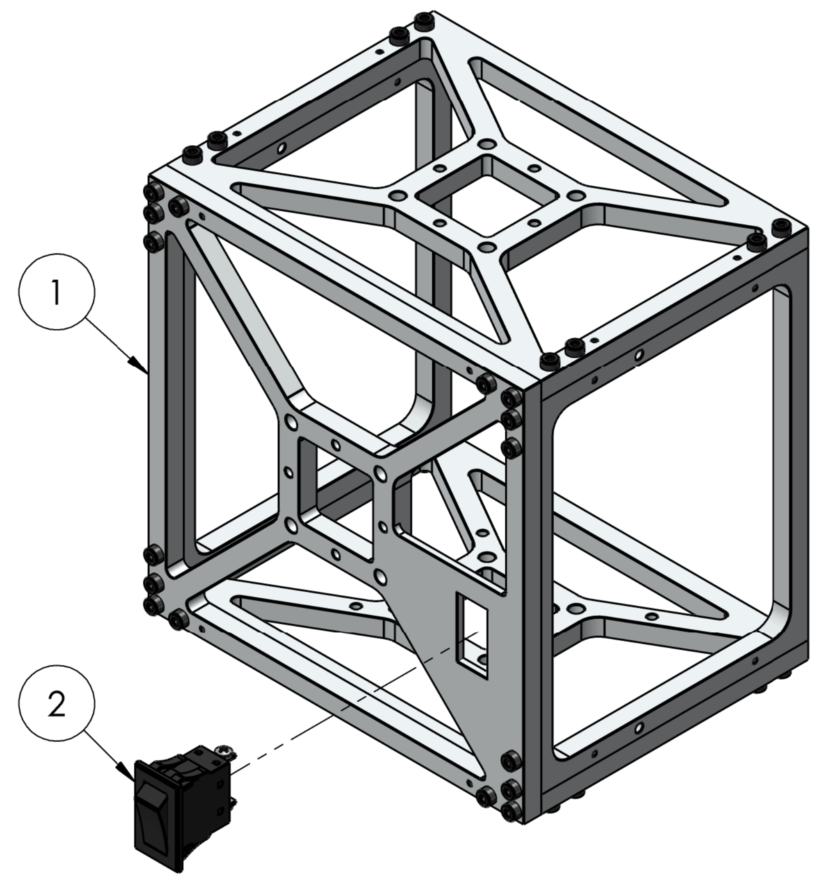
COMMENTS:

MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NEST**

PROJECT:	DWG NO.:		REV:
NEST	10000		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 8 OF 14



EXPLODED VIEW - STEP 1: SPDT SWITCH

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

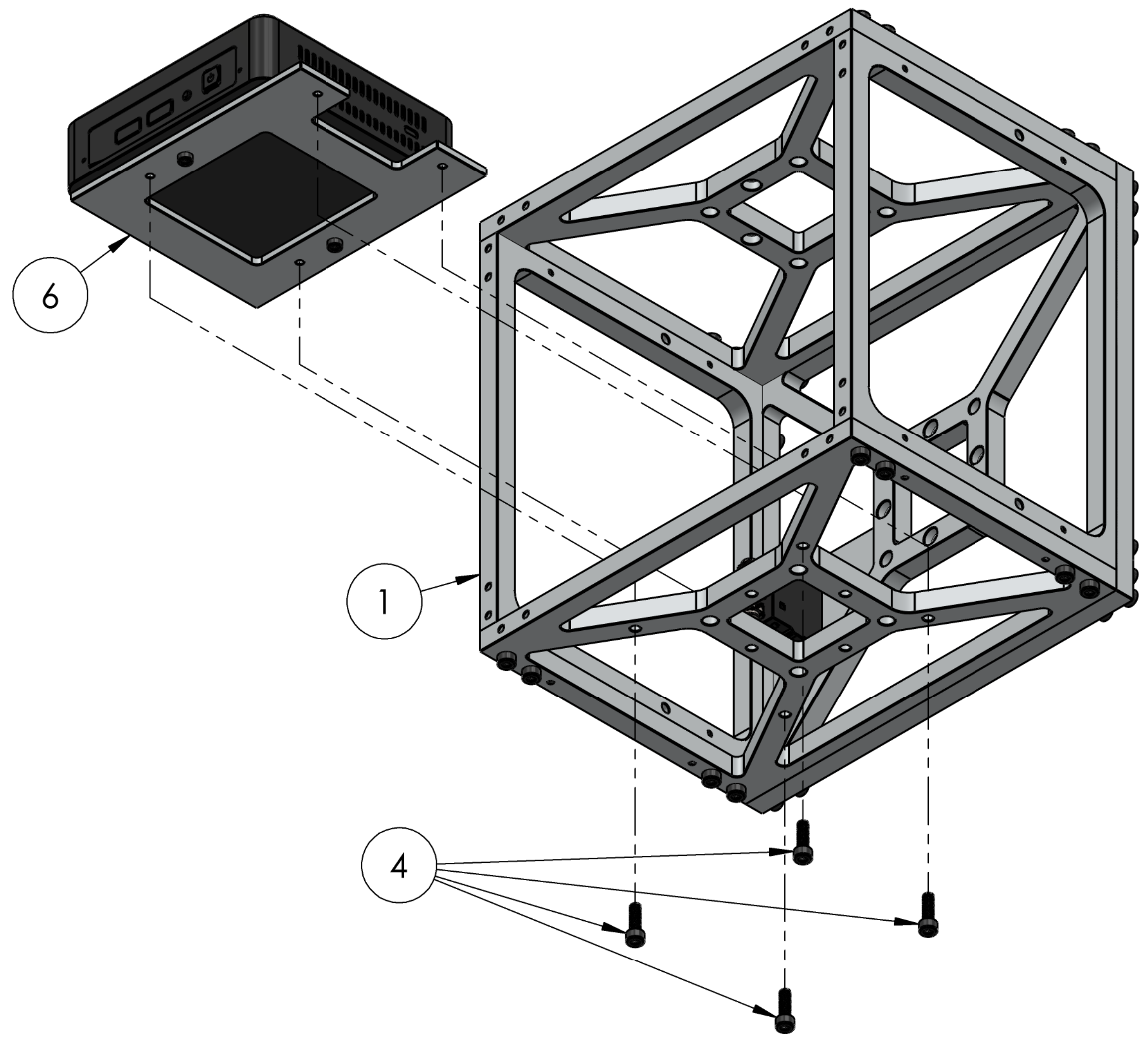
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

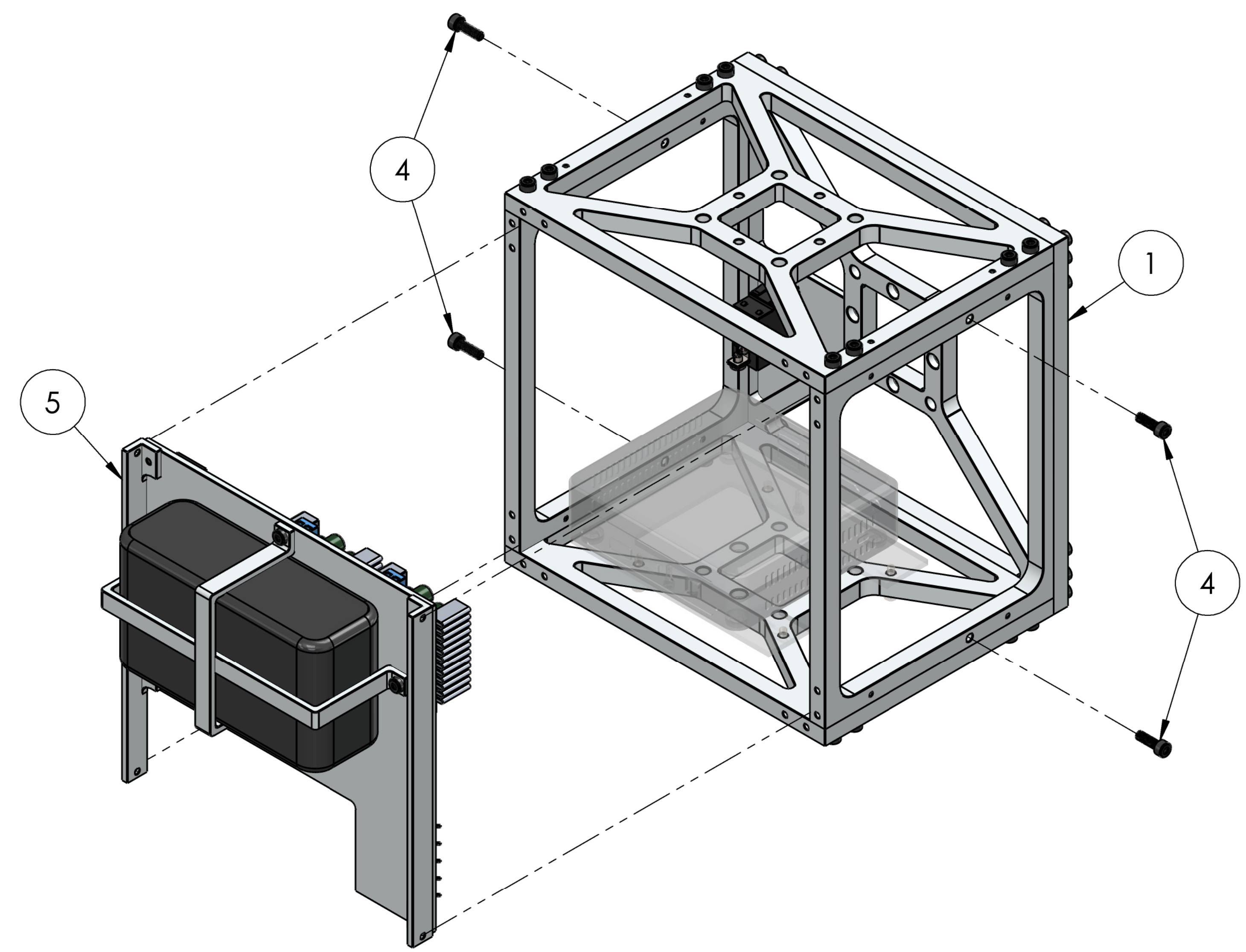
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:			
NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:3	SHEET: 9 OF 14



EXPLODED VIEW - STEP 2: NUC COMPUTER MOUNTING ASSEMBLY



EXPLODED VIEW - STEP 3: POWER ELECTRONICS ASSEMBLY

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

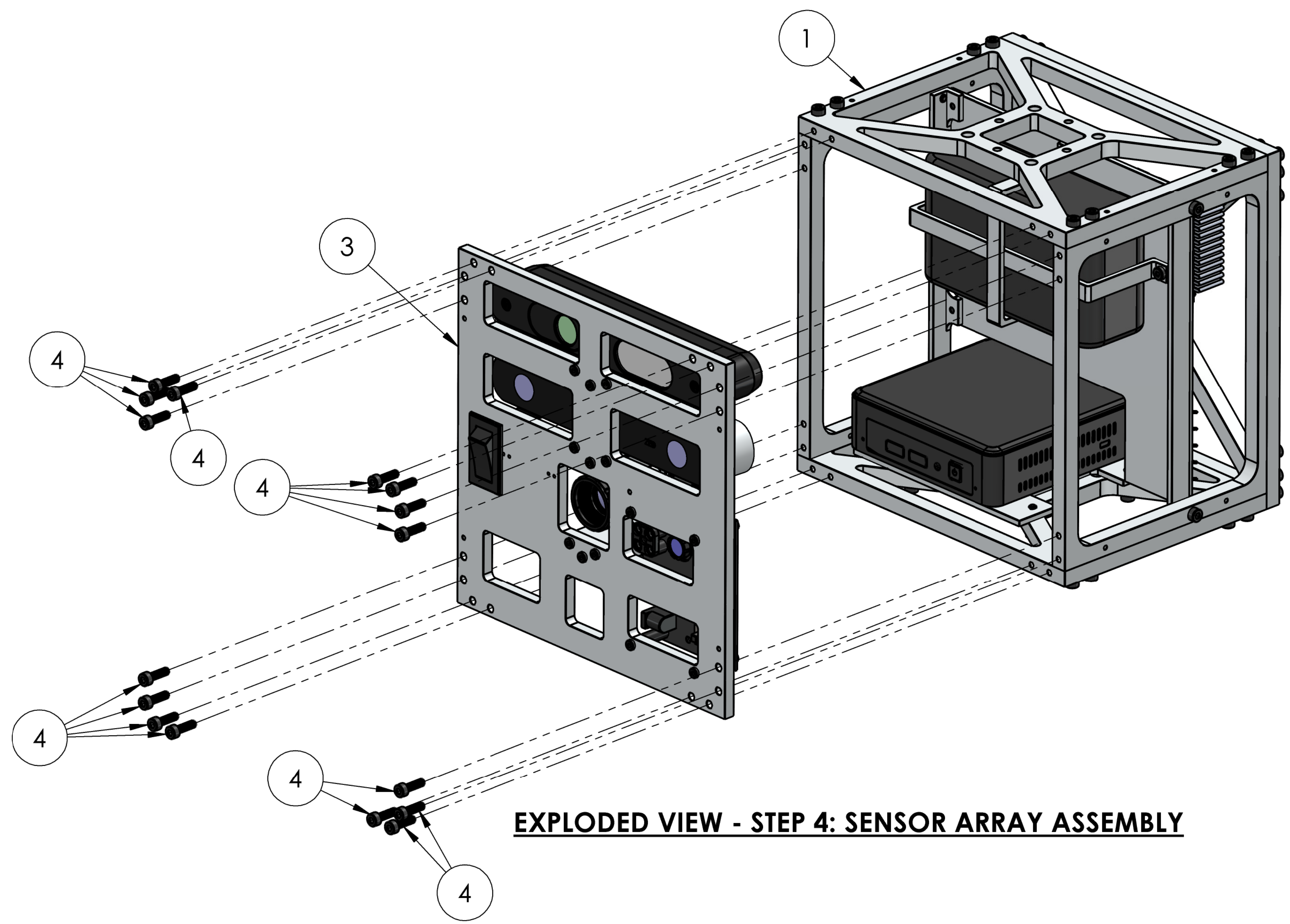
COMMENTS:

MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NEST**

PROJECT:	DWG NO.:		REV:
NEST	**10000**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:3	10 OF 14



EXPLODED VIEW - STEP 4: SENSOR ARRAY ASSEMBLY

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

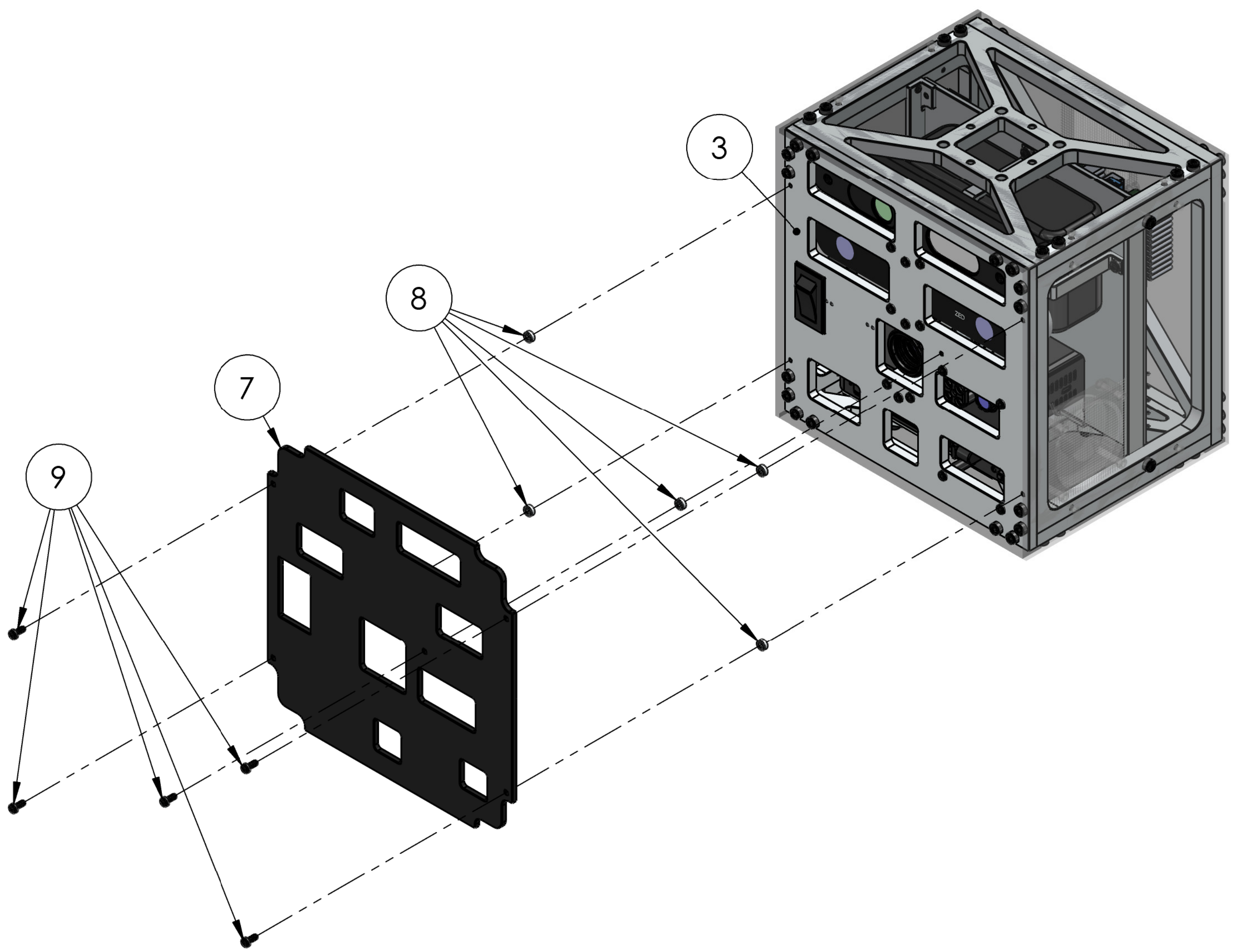
COMMENTS:

MATERIAL:

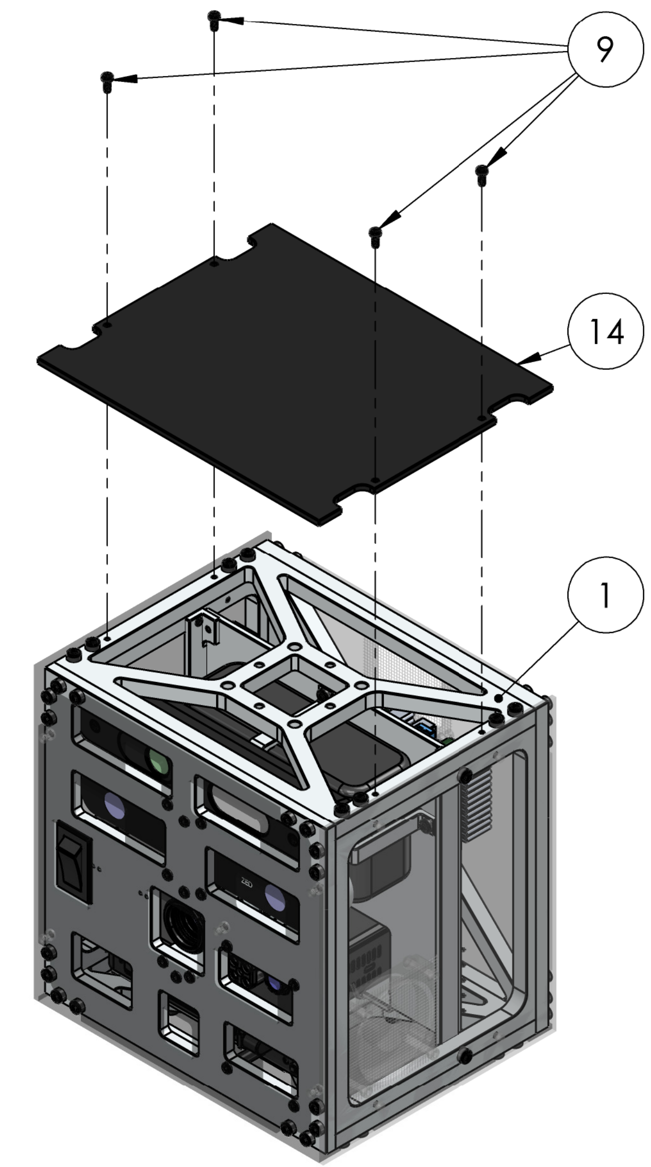
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NEST**

PROJECT:	DWG NO.:		REV:
NEST	10000		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:3	SHEET: 11 OF 14



EXPLODED VIEW - STEP 5A: FRONT SIDING



EXPLODED VIEW - STEP 5B: TOP SIDING

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

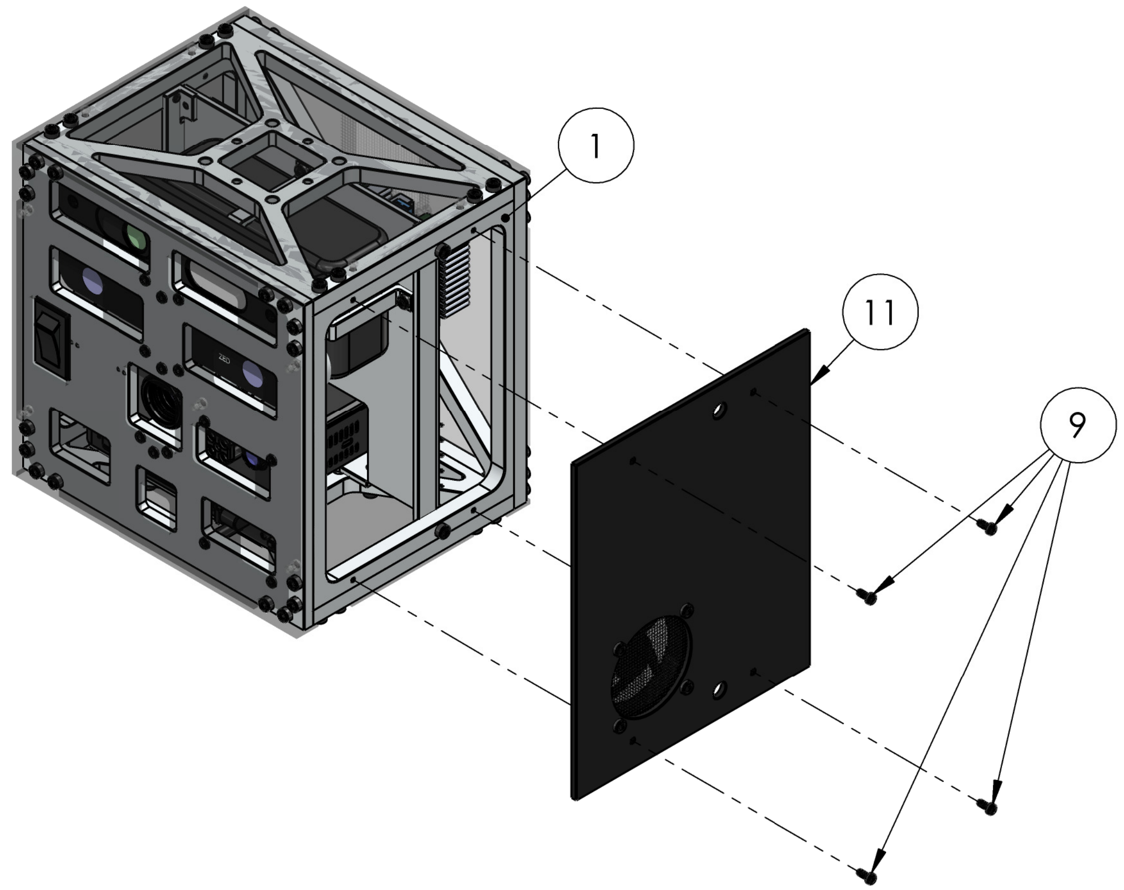
COMMENTS:

MATERIAL:

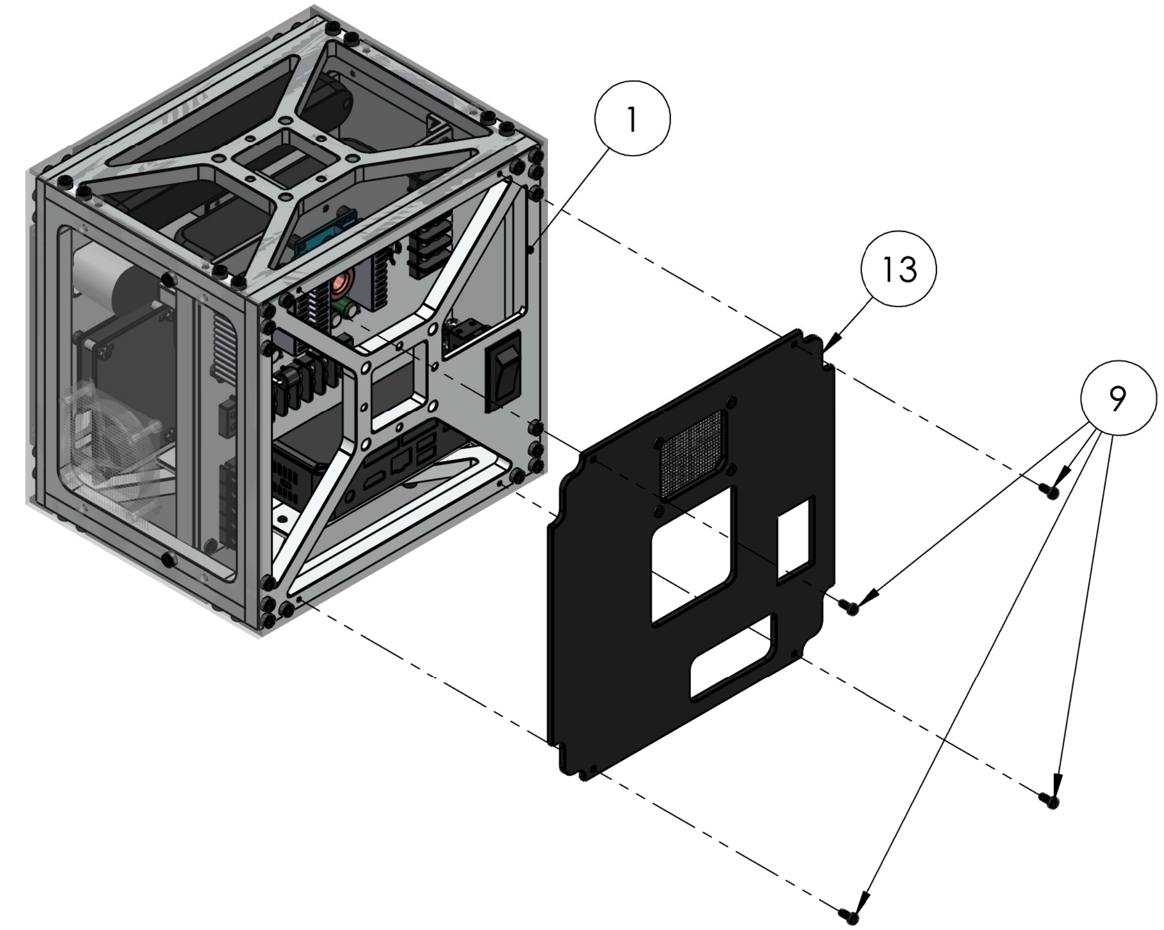
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NEST**

PROJECT:	DWG NO.:		REV:
NEST	10000		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:4	12 OF 14



EXPLODED VEIW - STEP 5C: LEFT SIDING



EXPLODED VIEW - STEP 5D: BACK SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

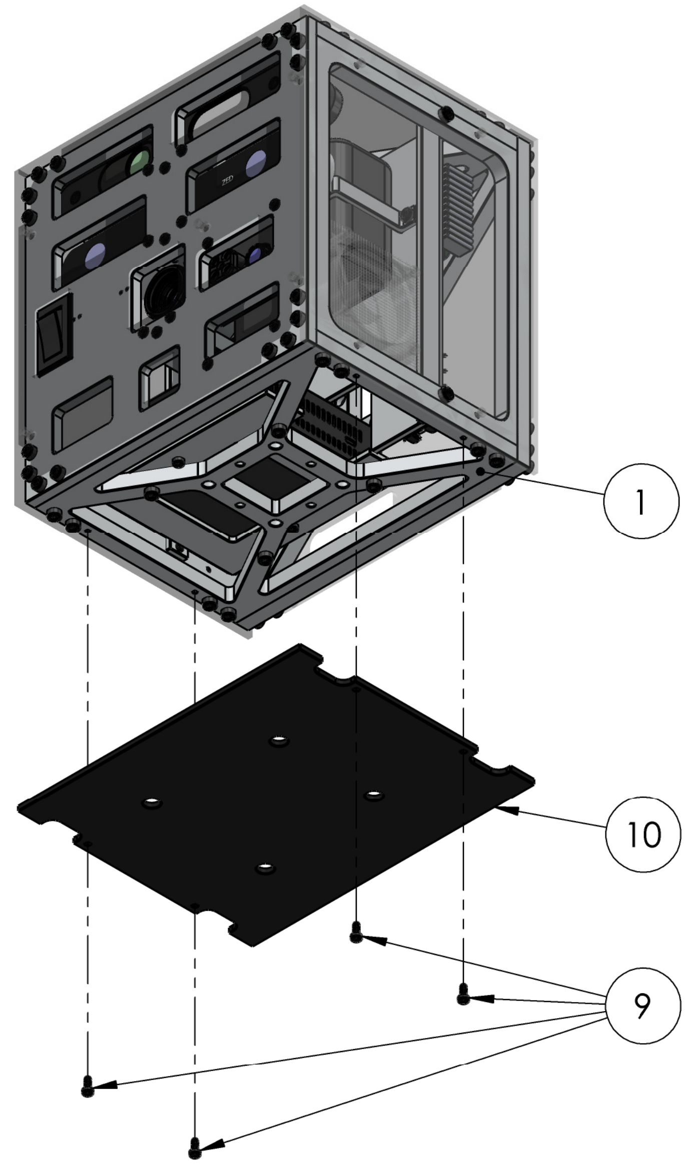
COMMENTS:

MATERIAL:

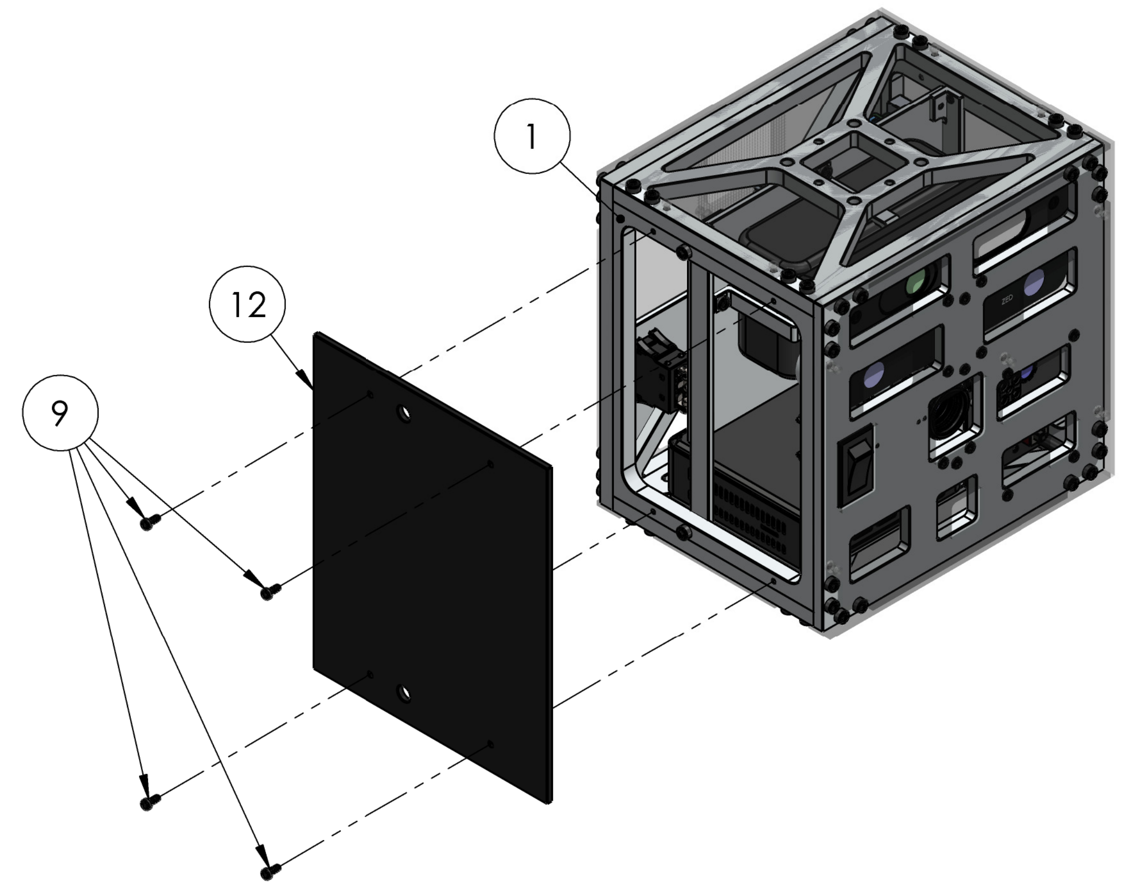
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NEST**

PROJECT:	DWG NO.:		REV:
NEST	10000		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:4	13 OF 14



EXPLODED VIEW - STEP 5E: BOTTOM SIDING



EXPLODED VIEW - STEP 5F: RIGHT SIDING

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

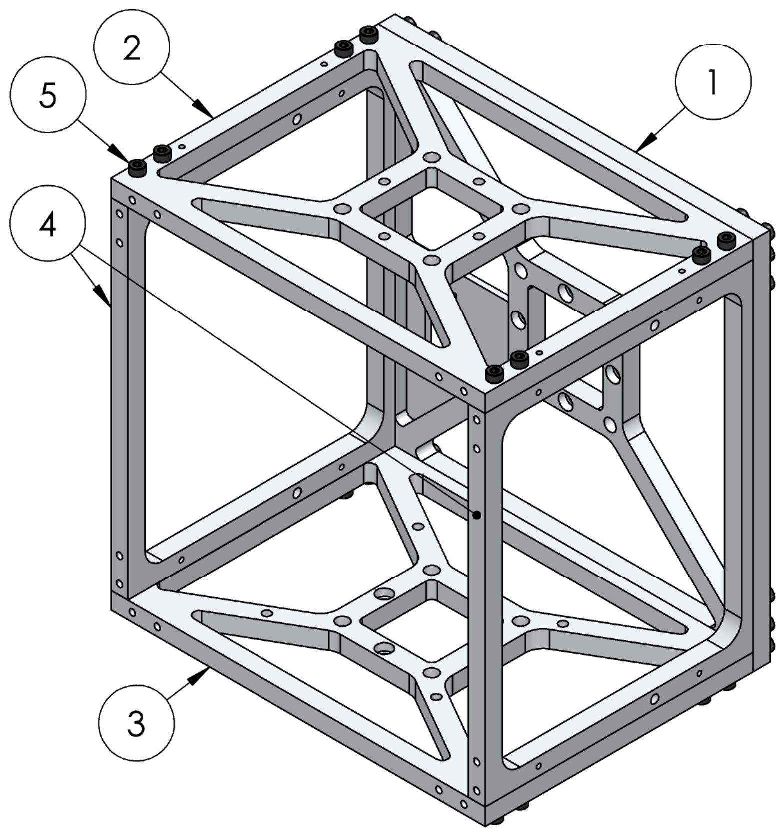
COMMENTS:

MATERIAL:

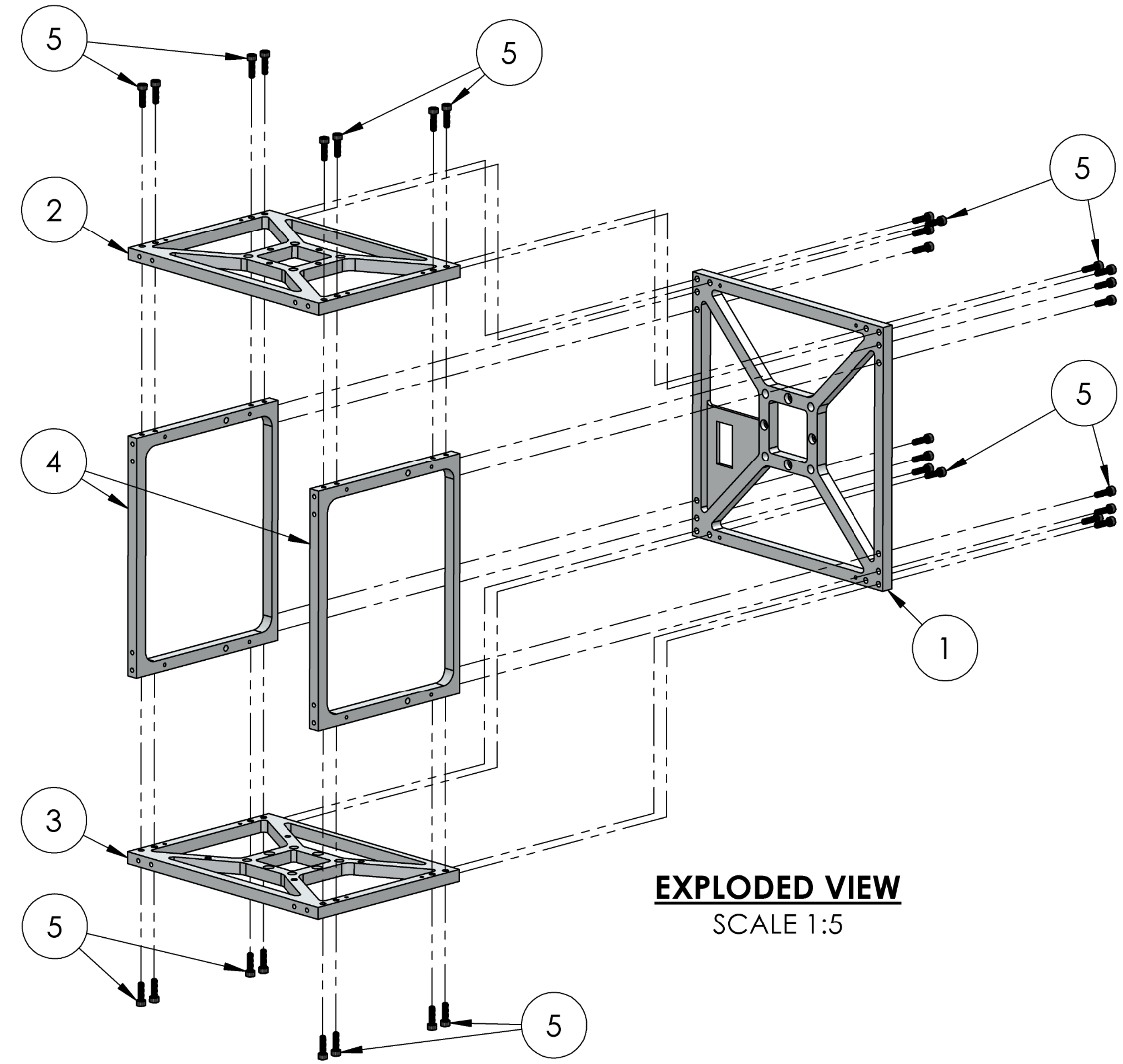
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: NEST			
PROJECT: NEST	DWG NO.: 10000		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:4	SHEET: 14 OF 14

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10111	CHASSIS BACK	1
2	10112	CHASSIS TOP	1
3	10113	CHASSIS BOTTOM	1
4	10114	CHASSIS SIDE	2
5	10943	M4x0.7 - 6H 14MM SOCKET HEAD SCREW	32



ISOMETRIC VIEW
SCALE 1 : 3



EXPLODED VIEW
SCALE 1:5

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

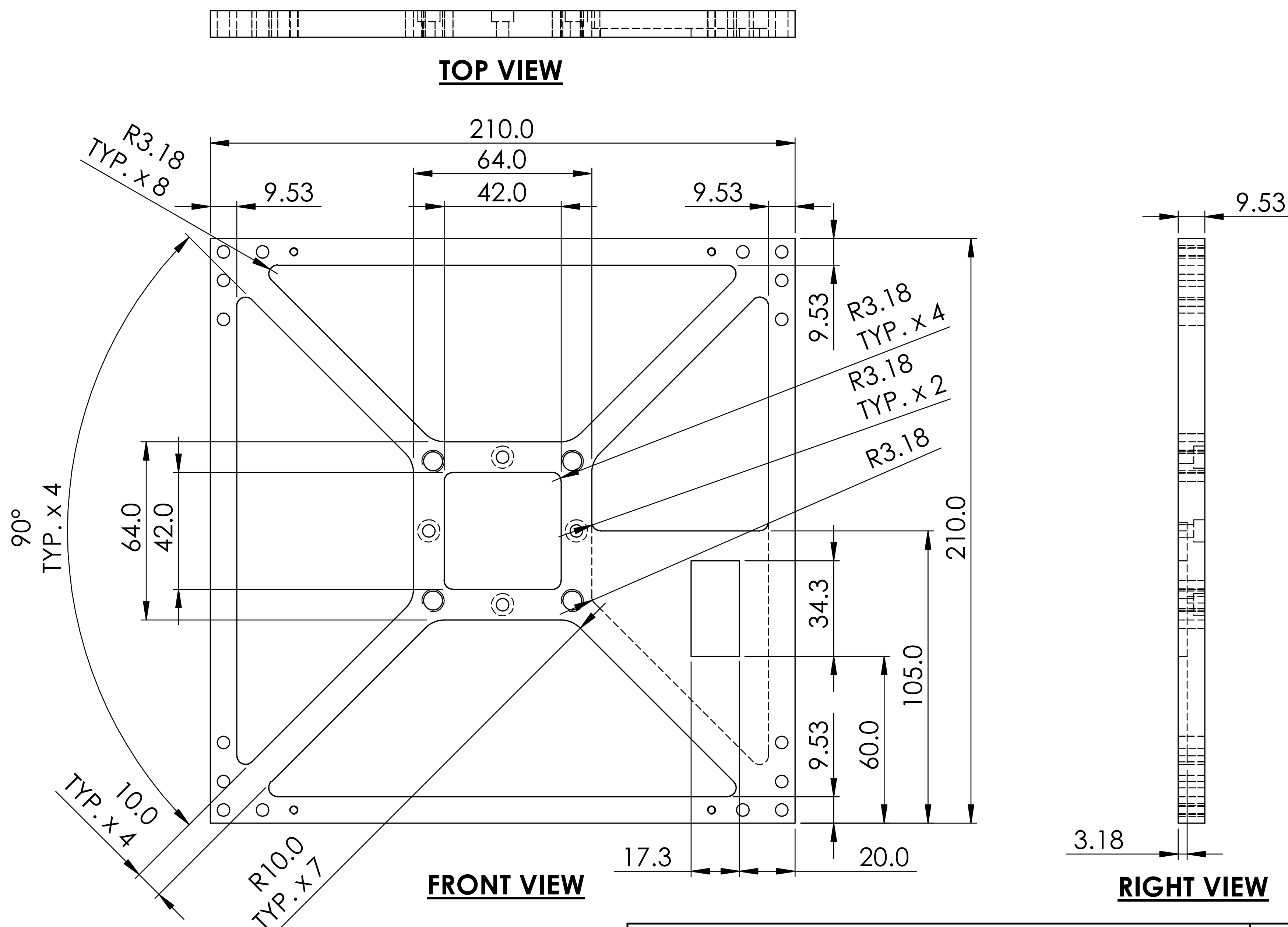
COMMENTS:

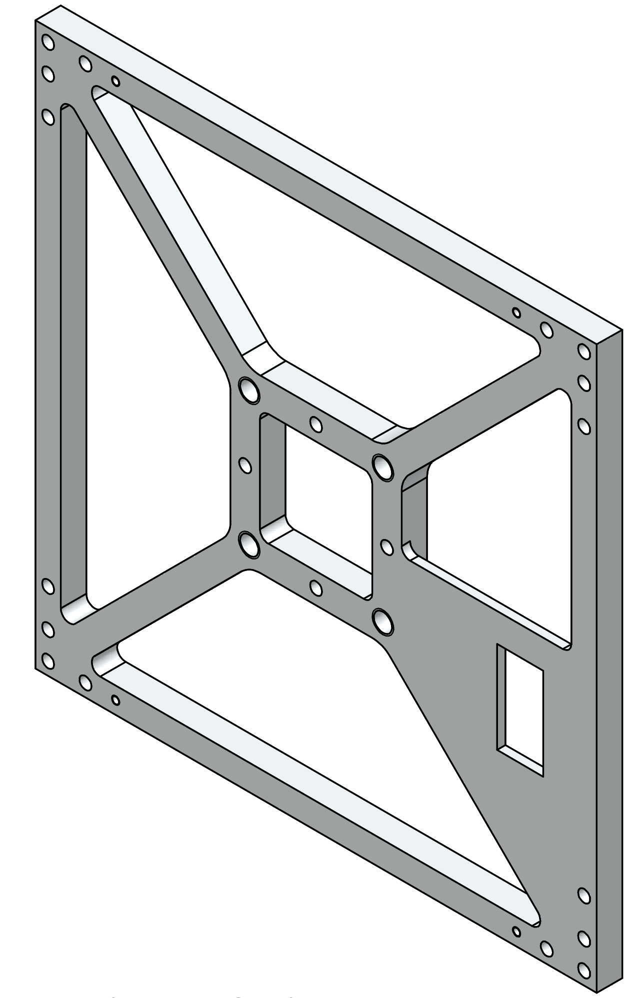
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS ASSEMBLY**

PROJECT:	DWG NO.:		REV:
NEST	10100		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B		1 OF 1





SHEET NOTES:

1. THE 9.53MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM PLATE. PART MAY BE LEFT AT THE STOCK PLATE THICKNESS.
2. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS THE THICKNESS OF THE THINNED SECTION ON WHICH THE SWITCH CUTOUT IS MADE.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

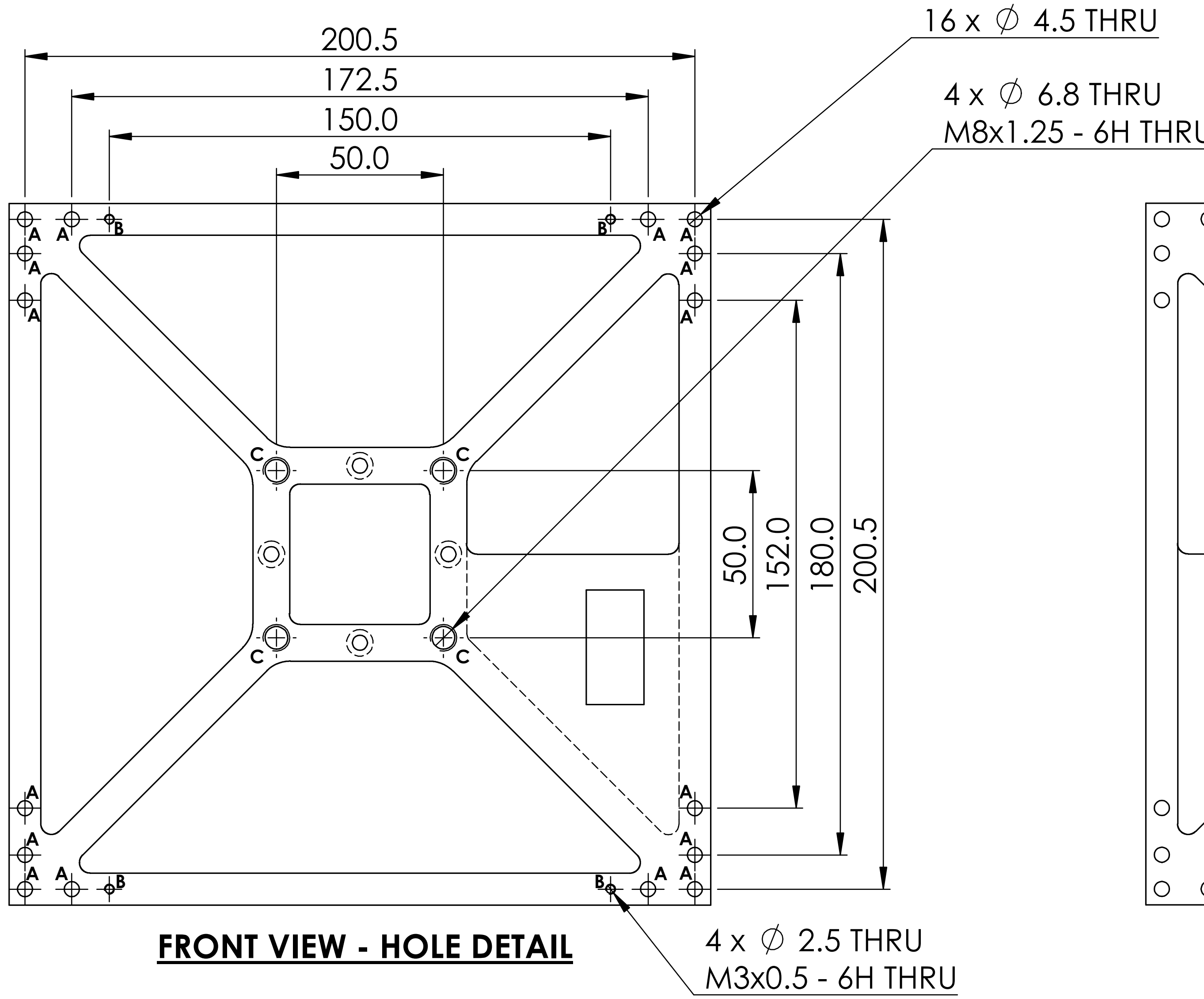
COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

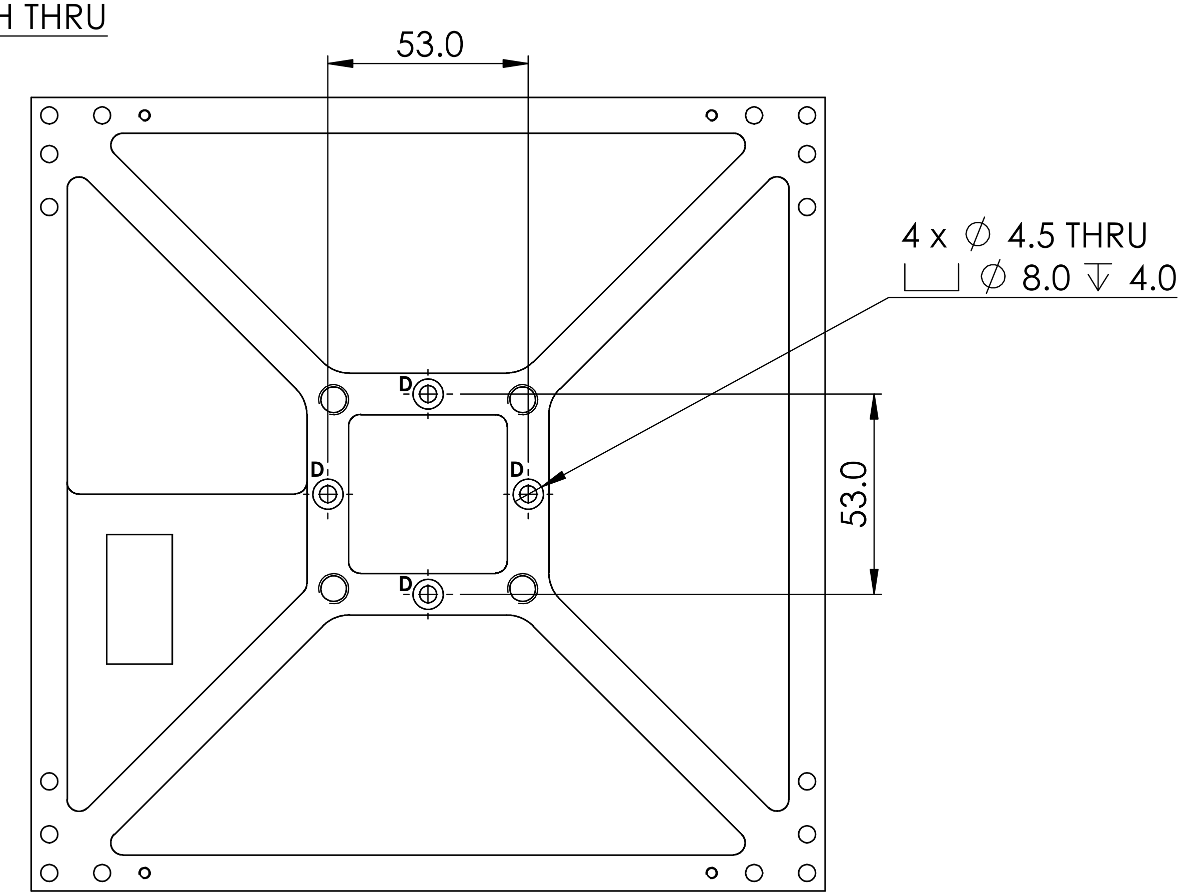
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: CHASSIS BACK			
PROJECT: NEST	DWG NO.: 10111		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 1 OF 2



FRONT VIEW - HOLE DETAIL



BACK VIEW - HOLE DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

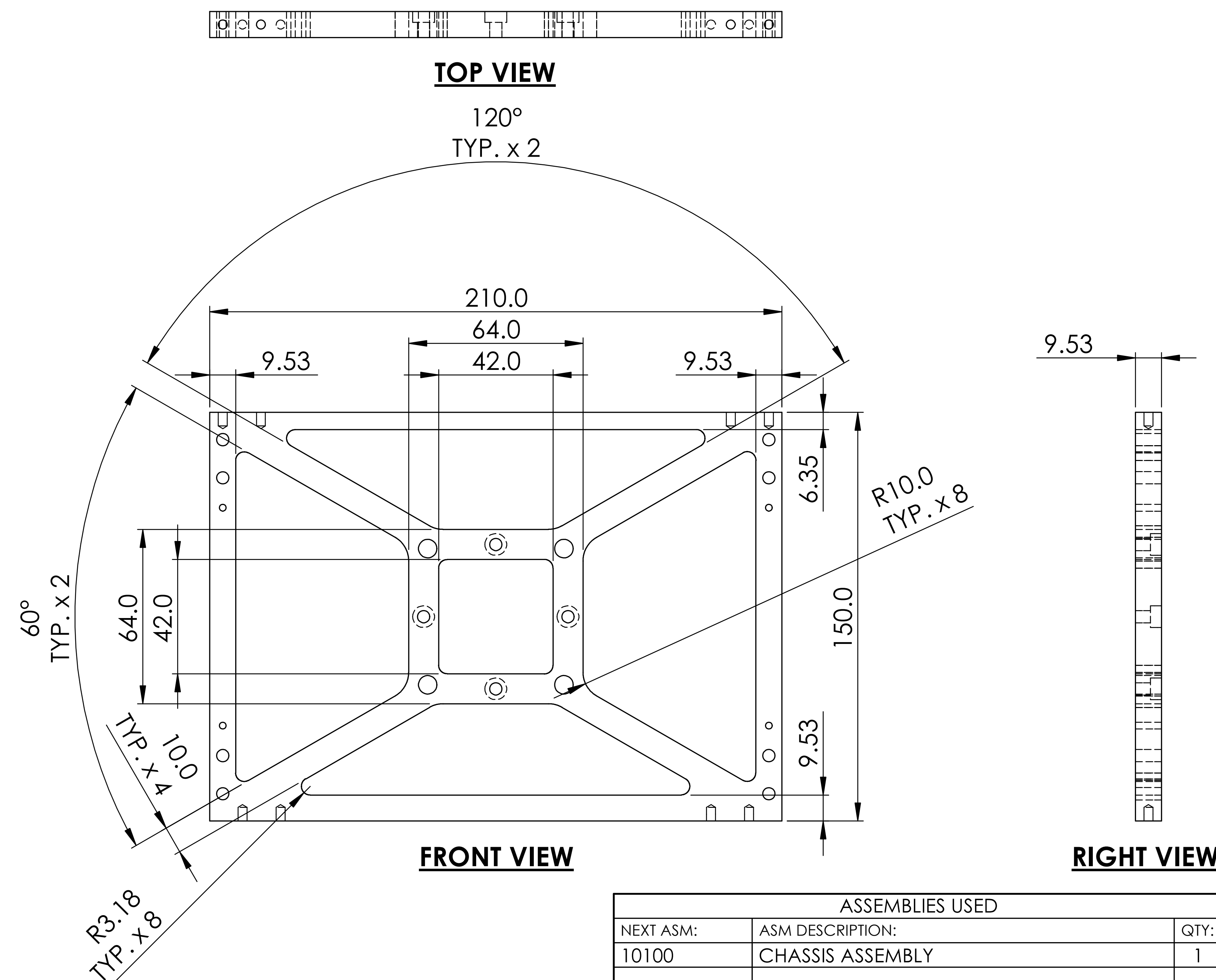
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

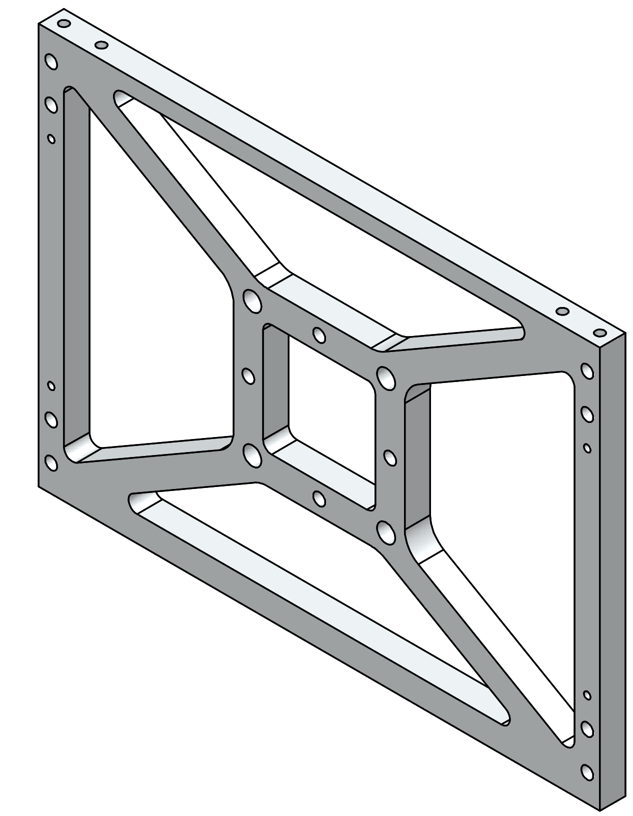
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS BACK**

PROJECT:	DWG NO.:		REV:
NEST	10111		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	2 OF 2





SHEET NOTES:

1. THE 9.53MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM PLATE. PART MAY BE LEFT AT THE STOCK PLATE THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

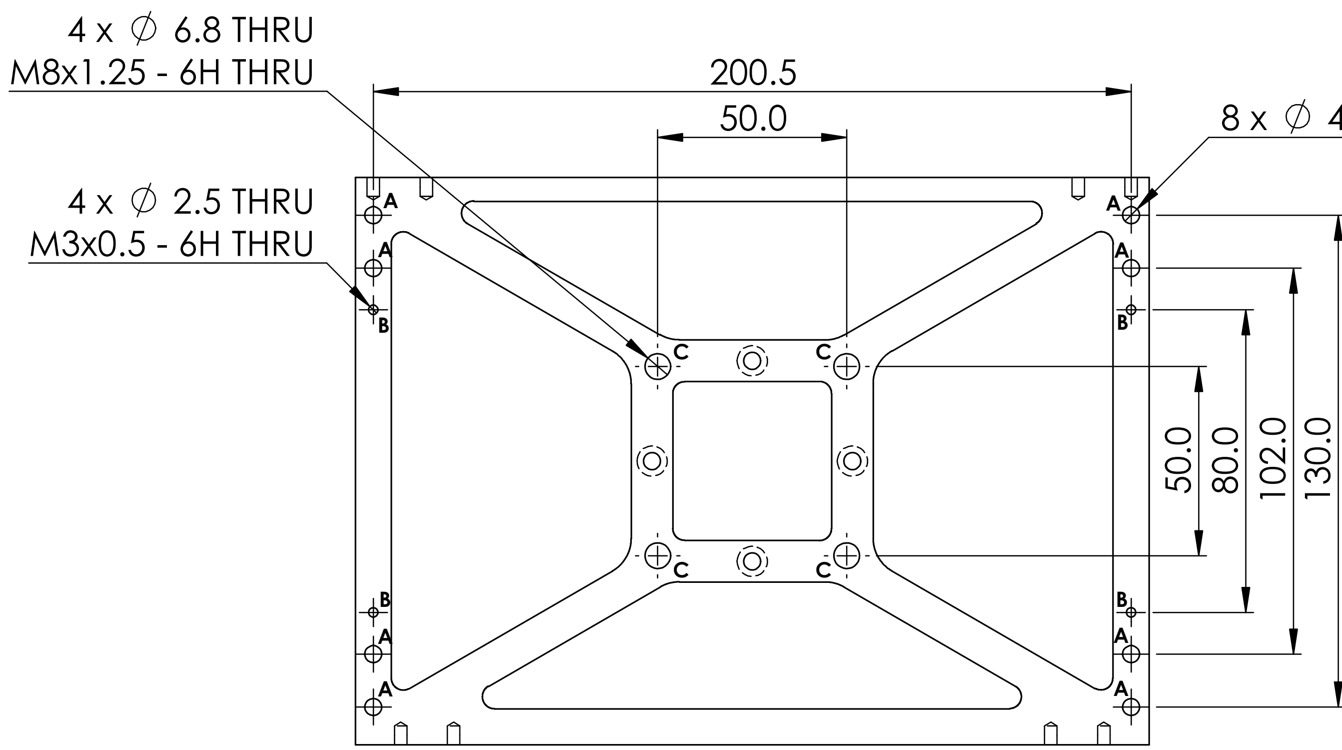
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

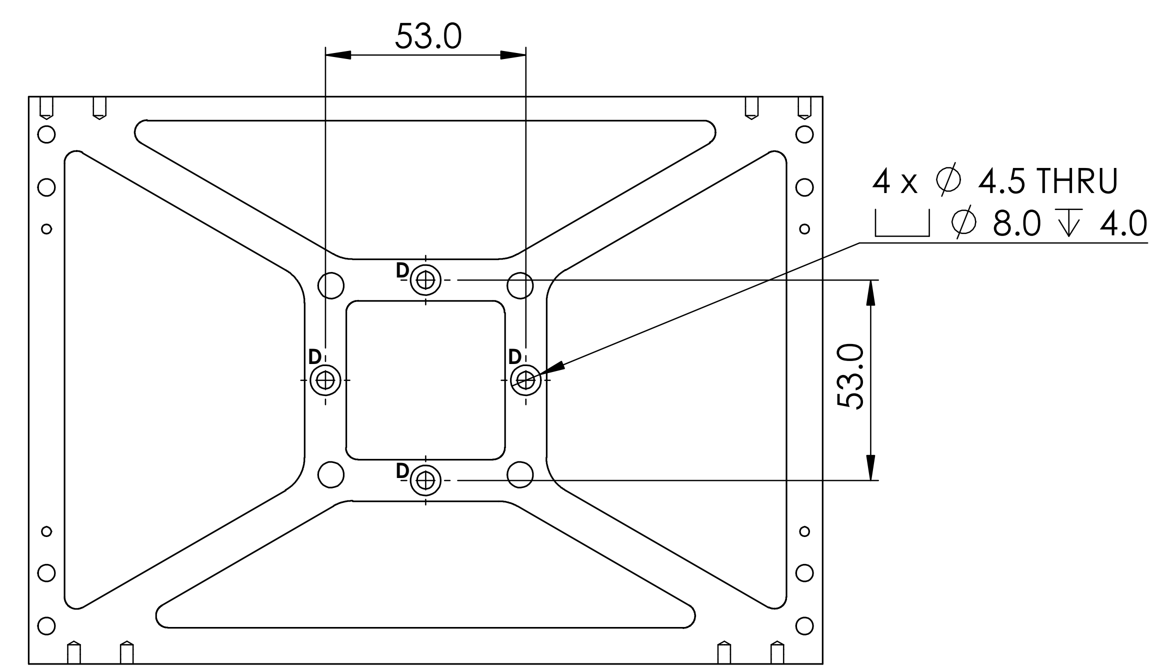
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS TOP**

PROJECT:	DWG NO.:		REV:
NEST	10112		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 3



FRONT VIEW - HOLE DETAIL



BACK VIEW - HOLE DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

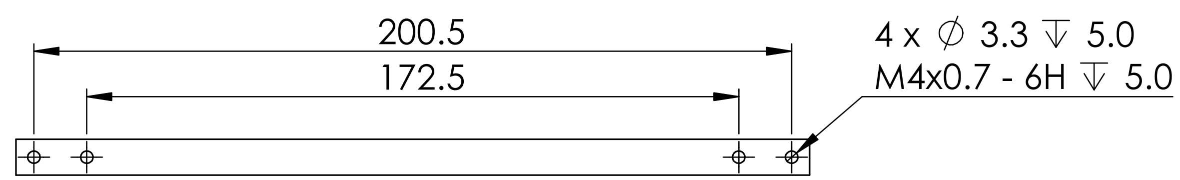
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

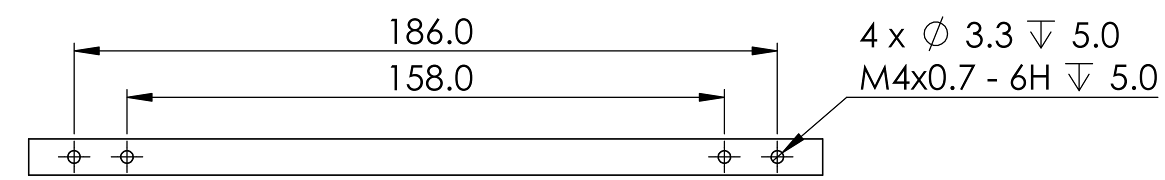
TITLE: **CHASSIS TOP**

PROJECT:	DWG NO.:	REV:
NEST	**10112**	0

DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	2 OF 3



TOP VIEW - HOLE DETAIL



BOTTOM VIEW - HOLE DETAIL

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

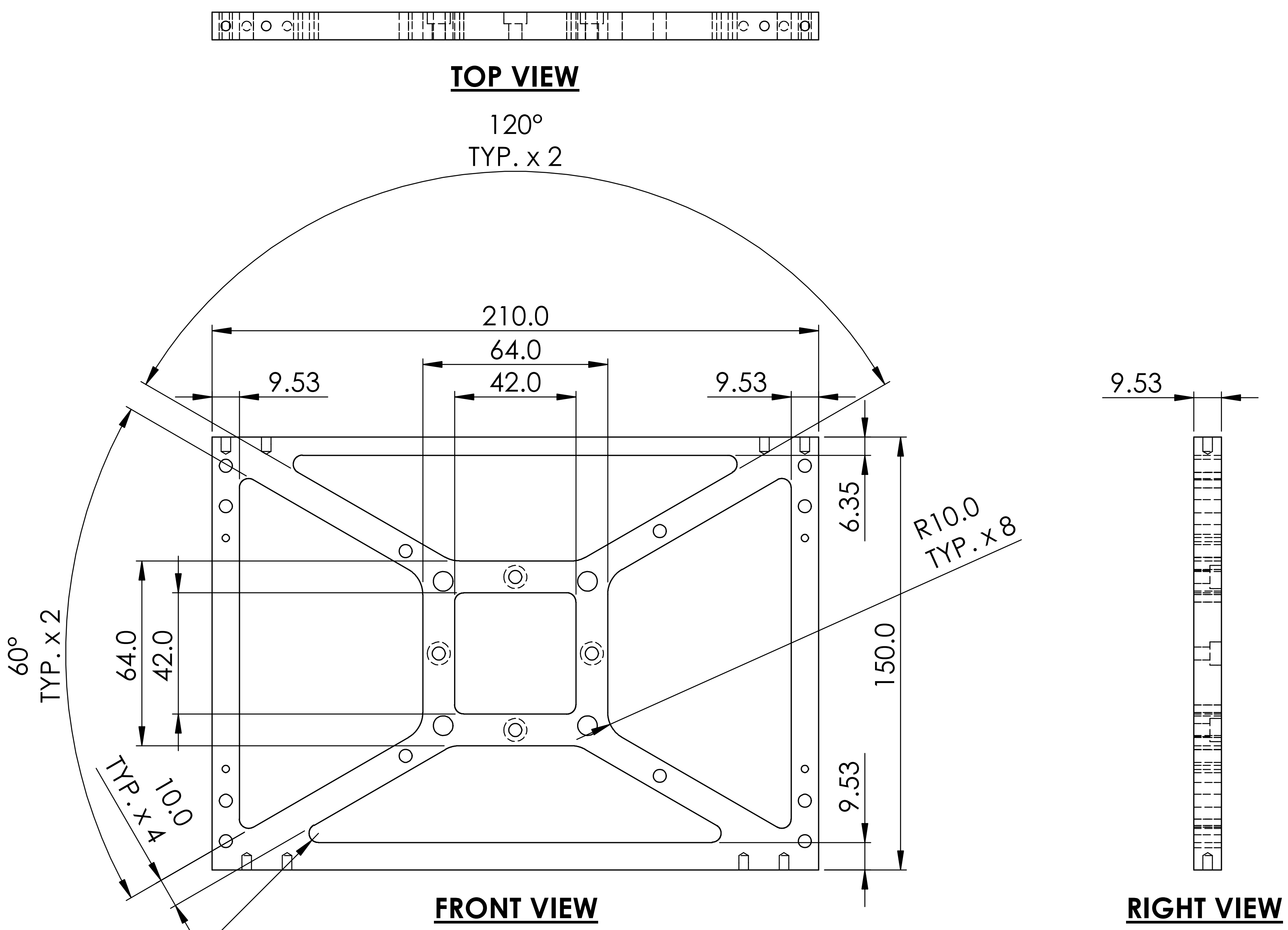
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

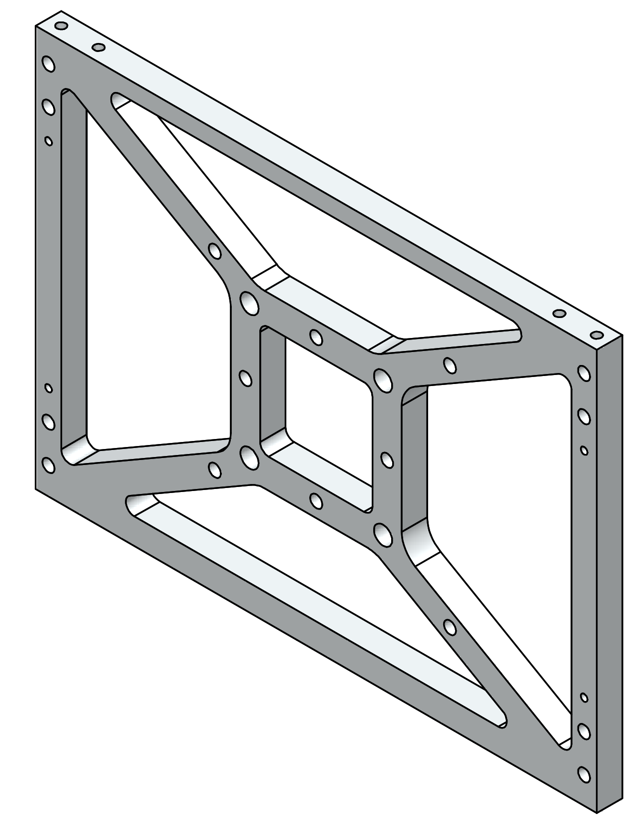
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS TOP**

PROJECT:	DWG NO.:		REV:
NEST	10112		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 3 OF 3





SHEET NOTES:

1. THE 9.53MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM PLATE. PART MAY BE LEFT AT THE STOCK PLATE THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

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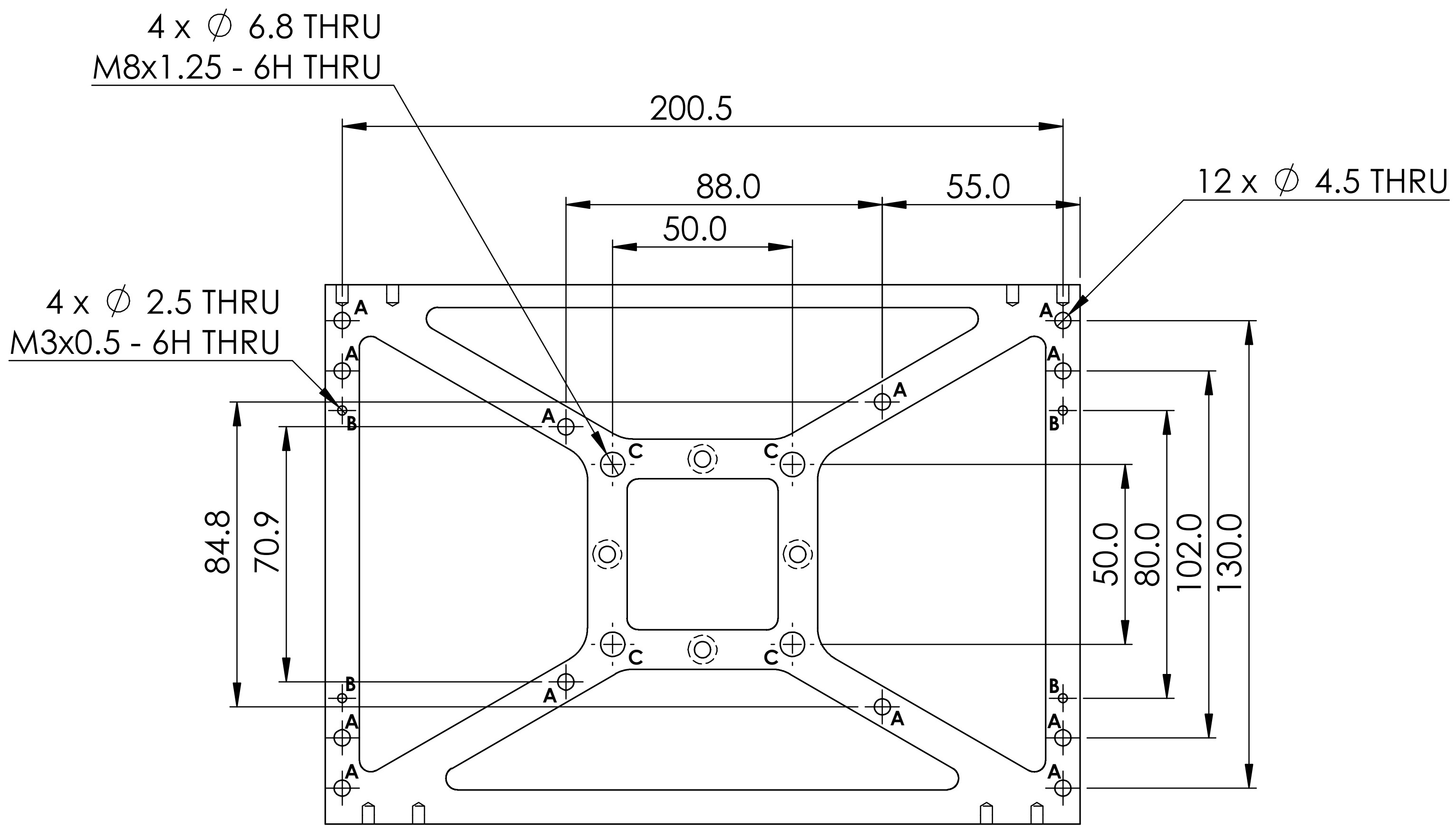
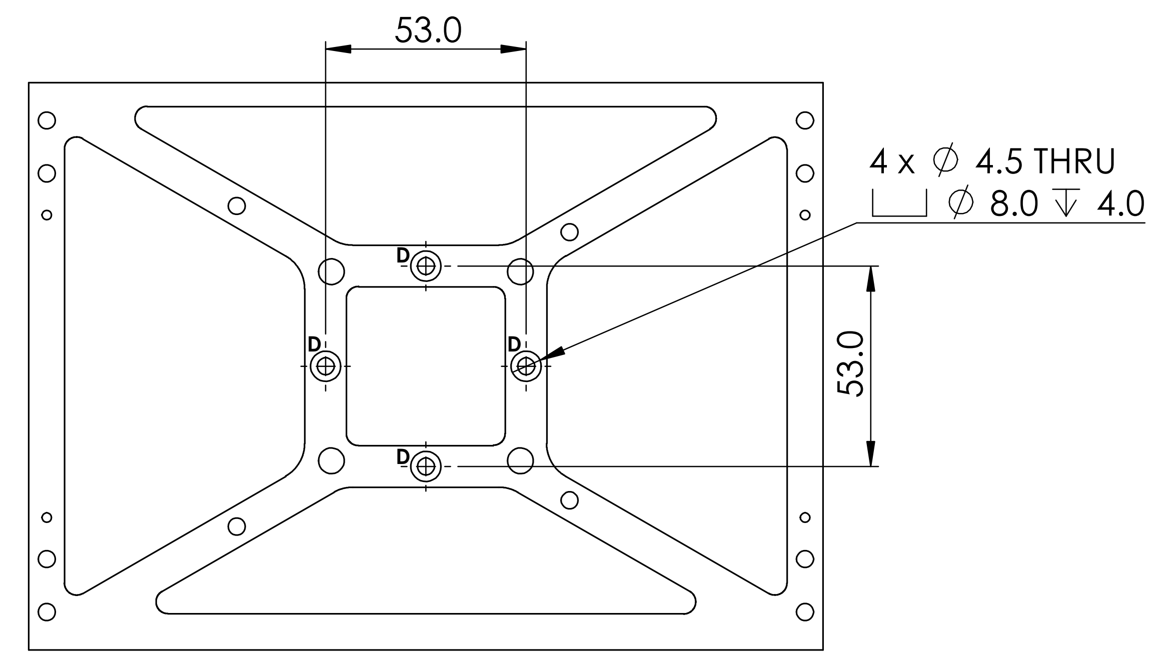
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS BOTTOM**

PROJECT:	DWG NO.:		REV:
NEST	10113		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 3



FRONT VIEW - HOLE DETAIL



BACK VIEW - HOLE DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

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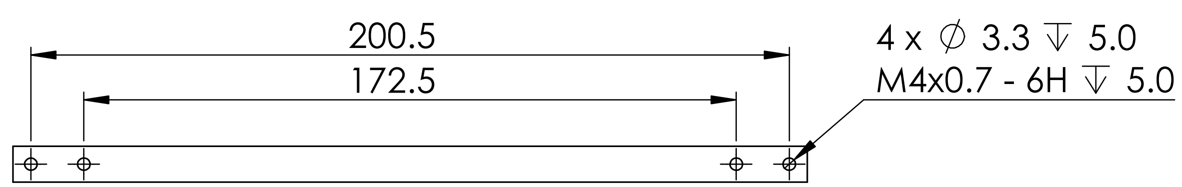
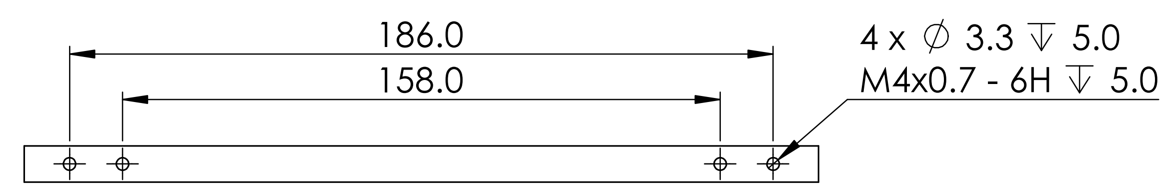
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS BOTTOM**

PROJECT:	DWG NO.:		REV:
NEST	**10113**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	2 OF 3



TOP VIEW - HOLE DETAIL



BOTTOM VIEW - HOLE DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

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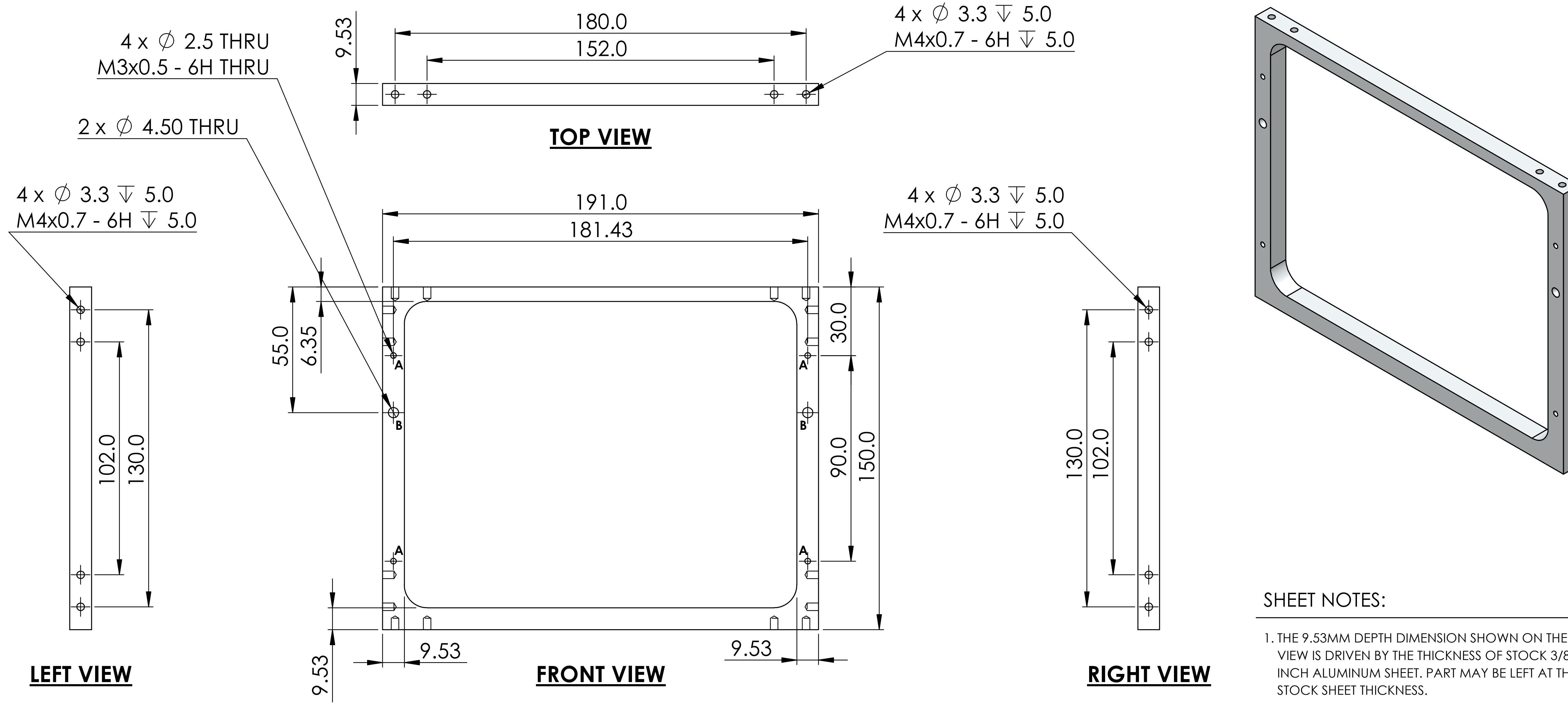
TEXAS A&M UNIVERSITY

TITLE: **CHASSIS BOTTOM**

PROJECT:	DWG NO.:		REV:
NEST	10113		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	3 OF 3



SHEET NOTES:

1. THE 9.53MM DEPTH DIMENSION SHOWN ON THE TOP VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	2

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

LASR
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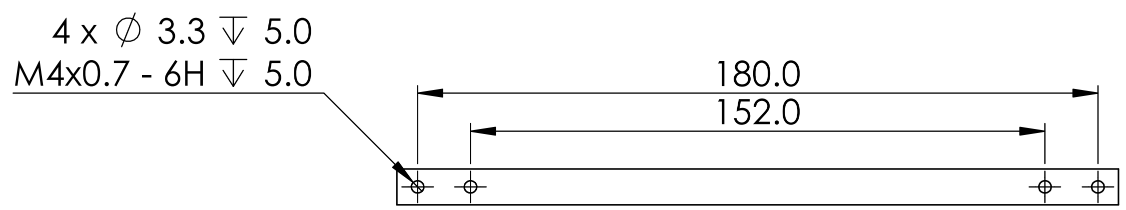
TEXAS A&M UNIVERSITY

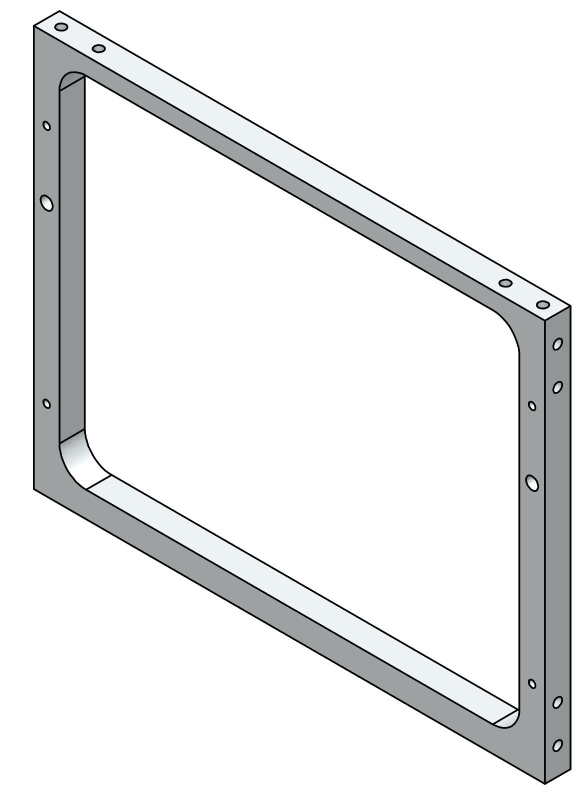
TITLE: **CHASSIS SIDE**

PROJECT:	DWG NO.:	REV:
NEST	10114	0

DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 2



BOTTOM VIEW



ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10100	CHASSIS ASSEMBLY	2

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

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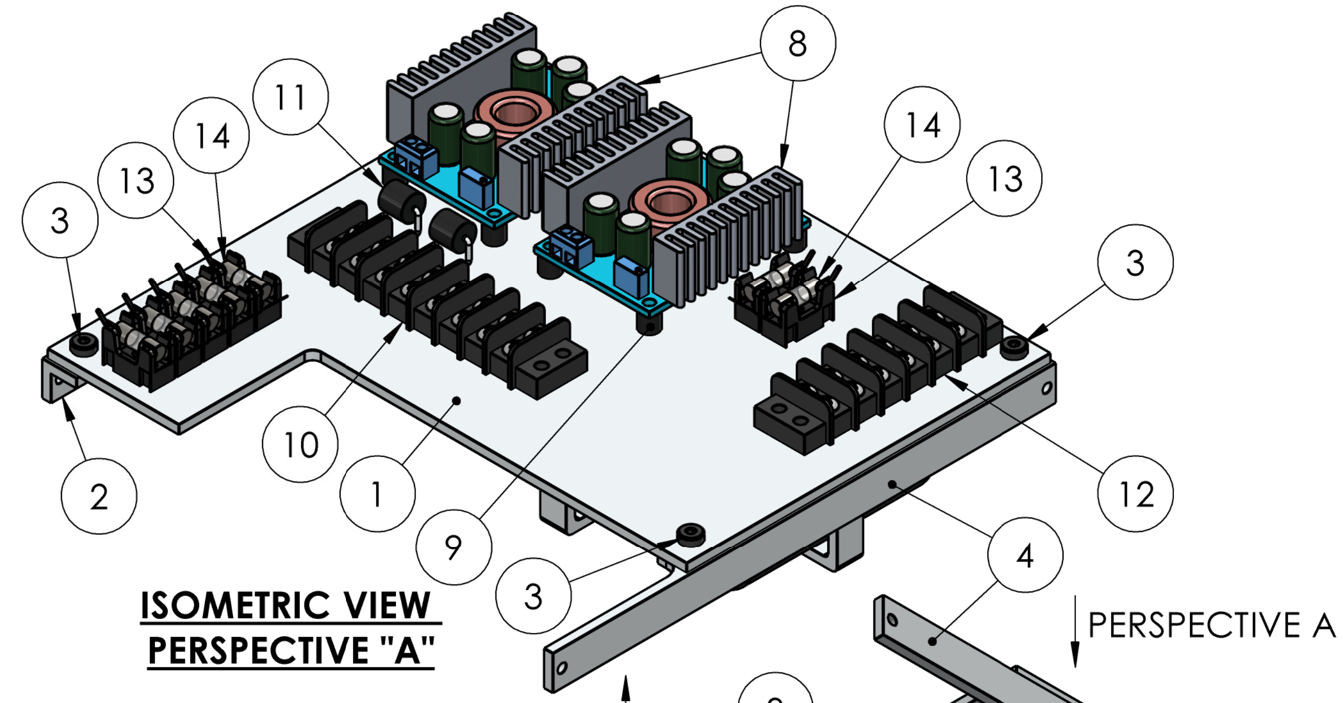
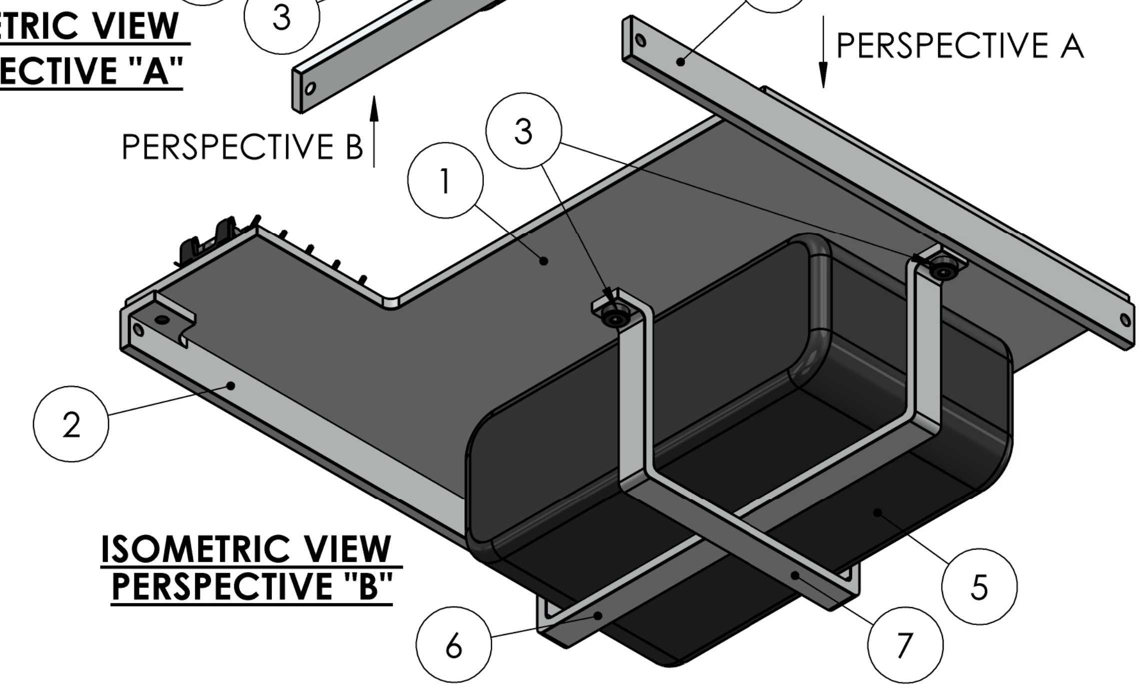
TITLE: **CHASSIS SIDE**

PROJECT:	DWG NO.:	REV:
NEST	10114	0

DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	2 OF 2

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10211	POWER ELECTRONICS PLATE	1
2	10212	LEFT POWER ELECTRONICS PLATE SUPPORT	1
3	10942	M4x0.7 - 6H 6MM LOW PROFILE SOCKET HEAD SCREW	8
4	10213	RIGHT POWER ELECTRONICS PLATE SUPPORT	1
5	10214	BATTERY	1
6	10215	BATTERY SUPPORT BRACKET - LENGTH	1
7	10216	BATTERY SUPPORT BRACKET - WIDTH	1
8	10217	DROK DC STEP-DOWN CONVERTER	2
9	10891	0.25" OD 1/4" NYLON SPACER	8
10	10219	TERMINAL BLOCK - 8 POLE	1
11	10220	DIODE	2
12	10218	TERMINAL BLOCK - 6 POLE	1
13	10221	FUDE HOLDER, 5MM X 15MM	7
14	10222	FUSE, 5MM X 15MM	7





SHEET NOTES:

1. PERSPECTIVE "A" IS AN ISOMETRIC VIEW OF THE POWER ELECTRONICS ASSEMBLY WITH THE TOP, FRONT, AND RIGHT SIDES VISIBLE. PERSPECTIVE "B" IS AN ISOMETRIC VIEW OF THE POWER ELECTRONICS ASSEMBLY WITH THE BOTTOM, FRONT, AND RIGHT SIDES VISIBLE.
2. THE DC CONVERTERS, SPACERS, FUSE HOLDERS, AND TERMINALS ARE PERMANENTLY ATTACHED TO THE POWER ELECTRONICS PLATE USING EPOXY RESIN. THESE COMPONENTS ARE LOCATED ON THE POWER ELECTRONICS PLATE APPROXIMATELY IN THEIR APPARENT POSITION, AND CAN BE PLACED BY VISUAL INSPECTION ALONE.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

MATERIAL:

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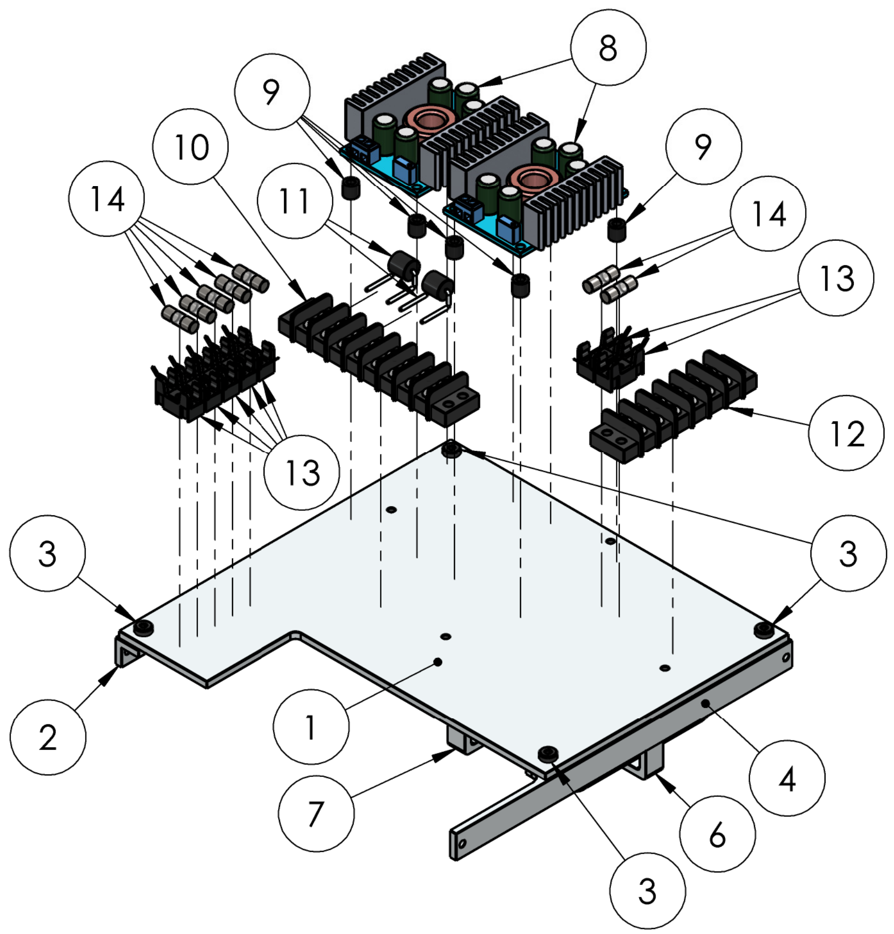
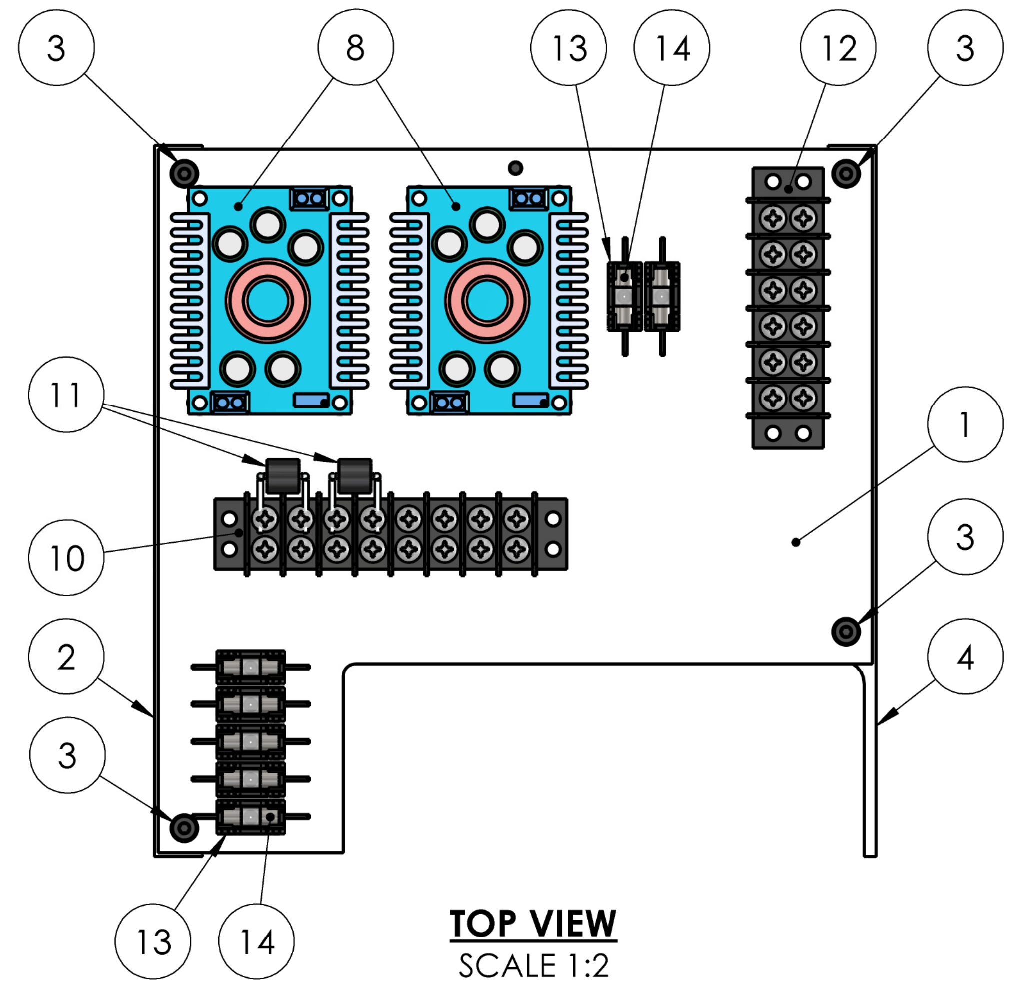
TEXAS A&M UNIVERSITY

TITLE: POWER ELECTRONICS ASSEMBLY			
PROJECT: NEST	DWG NO.: 10200		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 1 OF 3



EXPLODED VIEW - PERSPECTIVE "A"
SCALE 1:3



TOP VIEW
SCALE 1:2

SHEET NOTES:

1. PERSPECTIVE "A" IS AN ISOMETRIC VIEW OF THE POWER ELECTRONICS ASSEMBLY WITH THE TOP, FRONT, AND RIGHT SIDES VISIBLE.
2. THE DC CONVERTERS, SPACERS, FUSE HOLDERS, AND TERMINALS ARE PERMANENTLY ATTACHED TO THE POWER ELECTRONICS PLATE USING EPOXY RESIN. THESE COMPONENTS ARE LOCATED ON THE POWER ELECTRONICS PLATE APPROXIMATELY IN THEIR APPARENT POSITION, AND CAN BE PLACED BY VISUAL INSPECTION ALONE.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

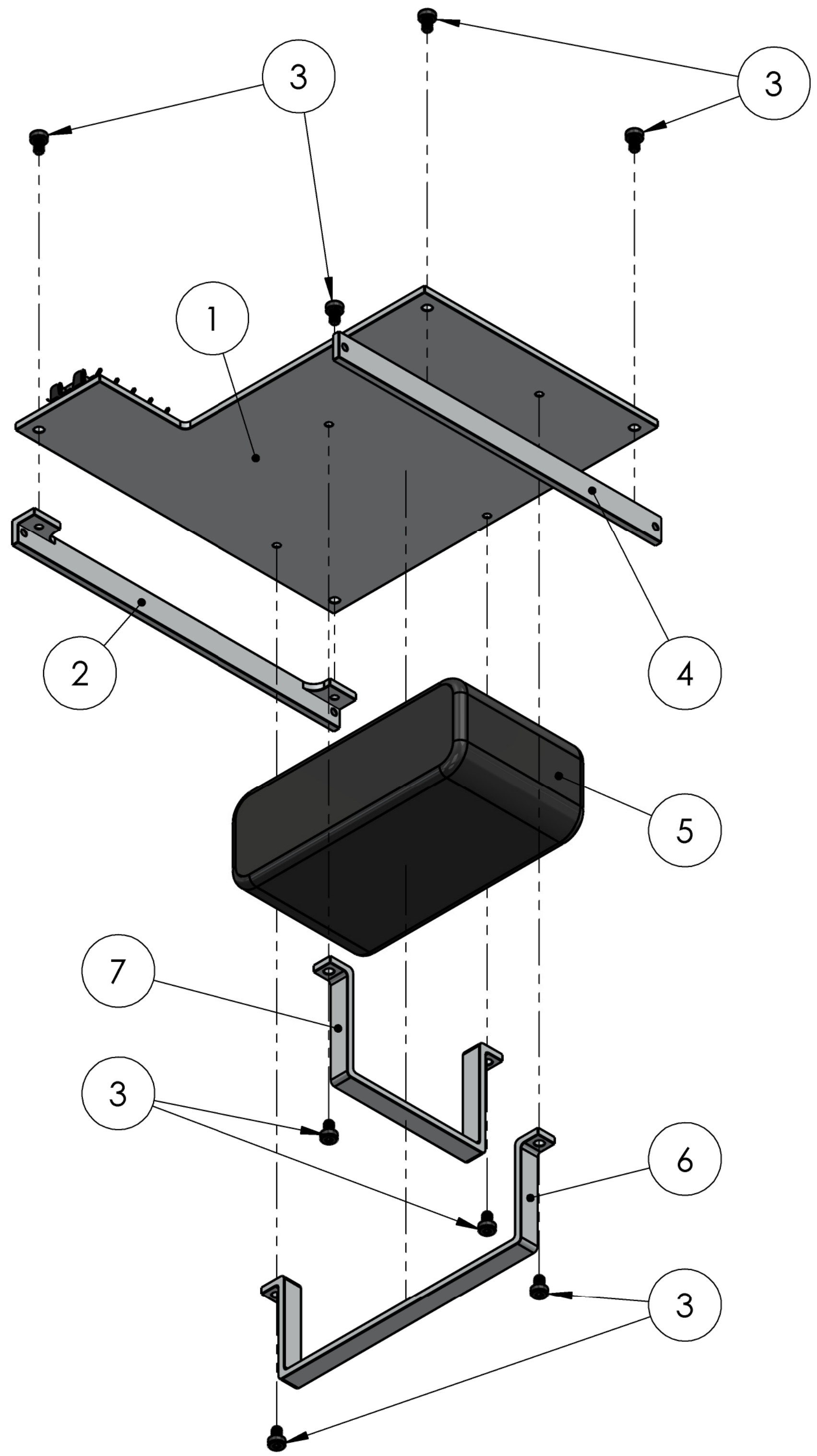
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

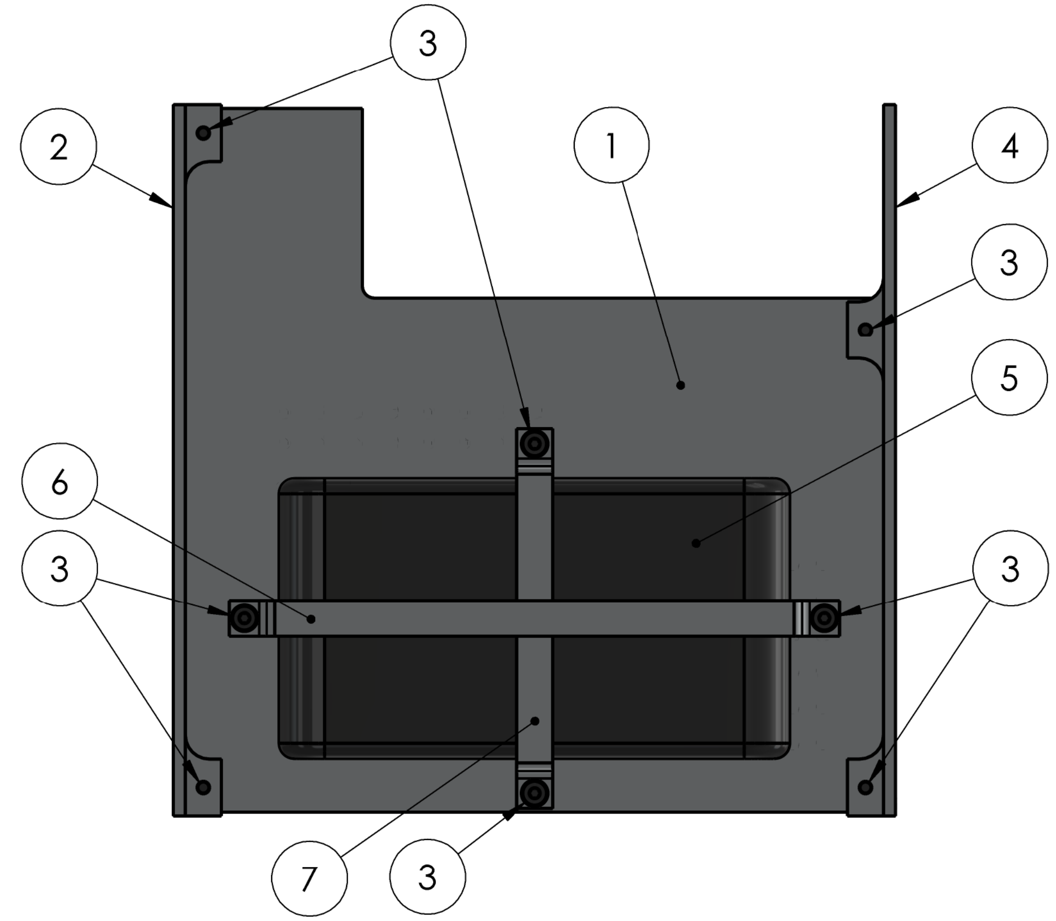
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: POWER ELECTRONICS ASSEMBLY			
PROJECT: NEST	DWG NO.: 10200		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE:	SHEET: 2 OF 3



EXPLODED VIEW - PERSPECTIVE "B"
SCALE 1:3



BOTTOM VIEW
SCALE 1:2

SHEET NOTES:

1. PERSPECTIVE "B" IS AN ISOMETRIC VIEW OF THE POWER ELECTRONICS ASSEMBLY WITH THE BOTTOM, FRONT, AND RIGHT SIDES VISIBLE.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

MATERIAL:

LASR
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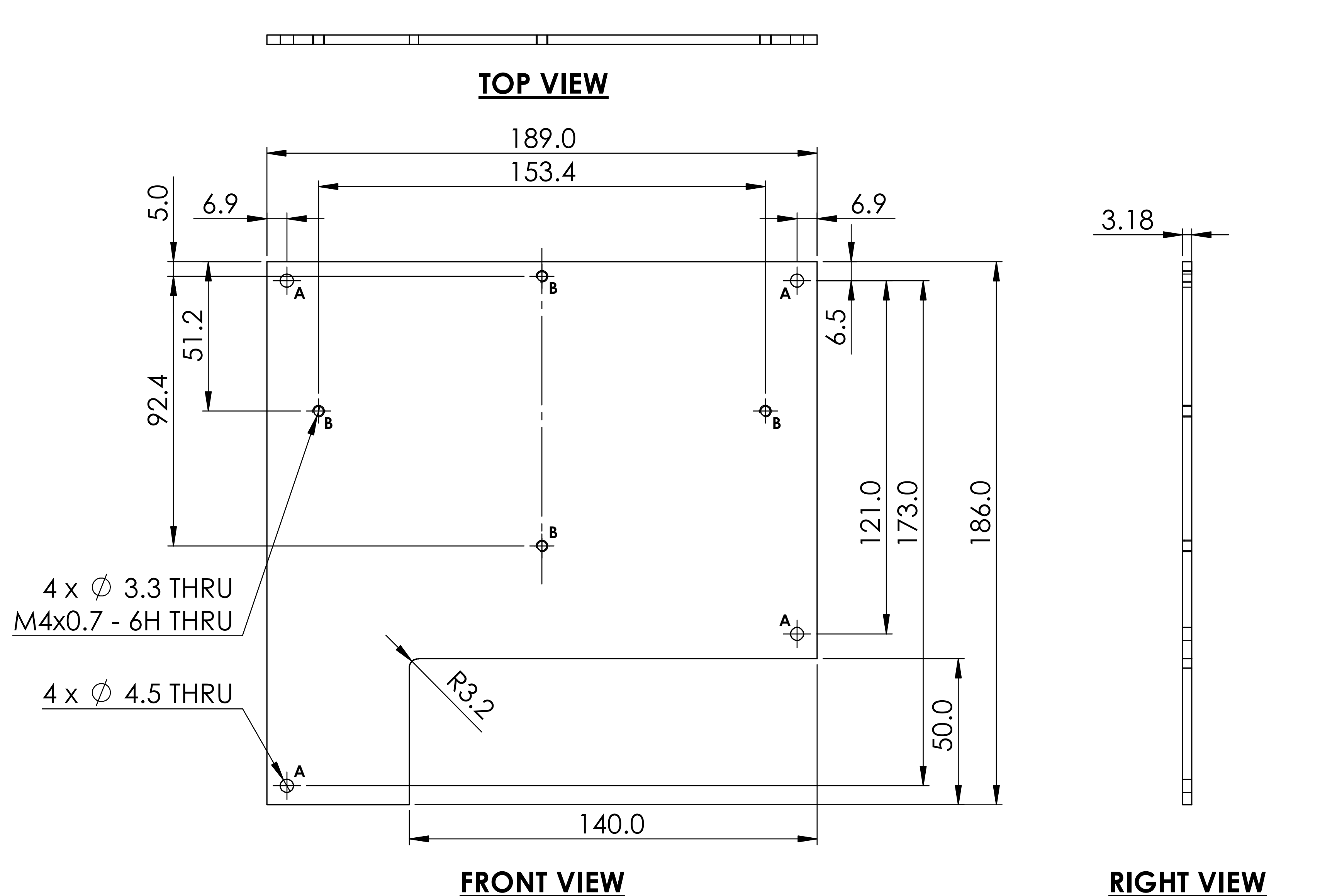
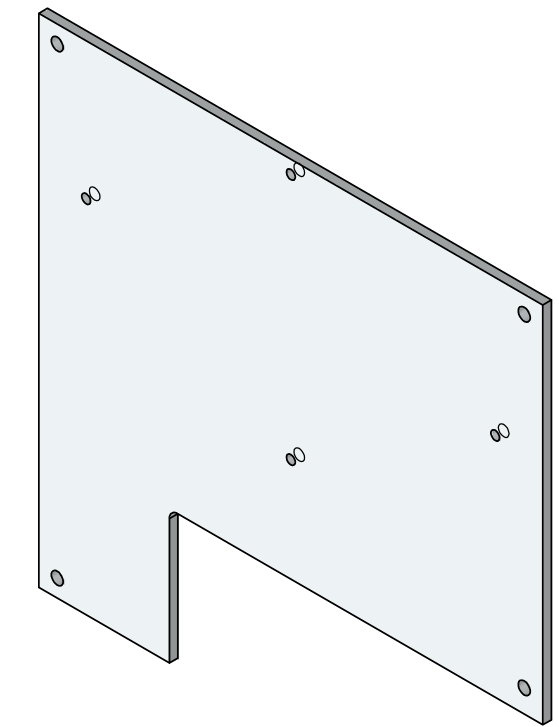
TEXAS A&M UNIVERSITY

TITLE: **POWER ELECTRONICS ASSEMBLY**			
PROJECT: NEST	DWG NO.: **10200**		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE:	SHEET: 3 OF 3





SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ALUMINIM PLATE. PART MAY BE LEFT AT THE STOCK PLATE THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

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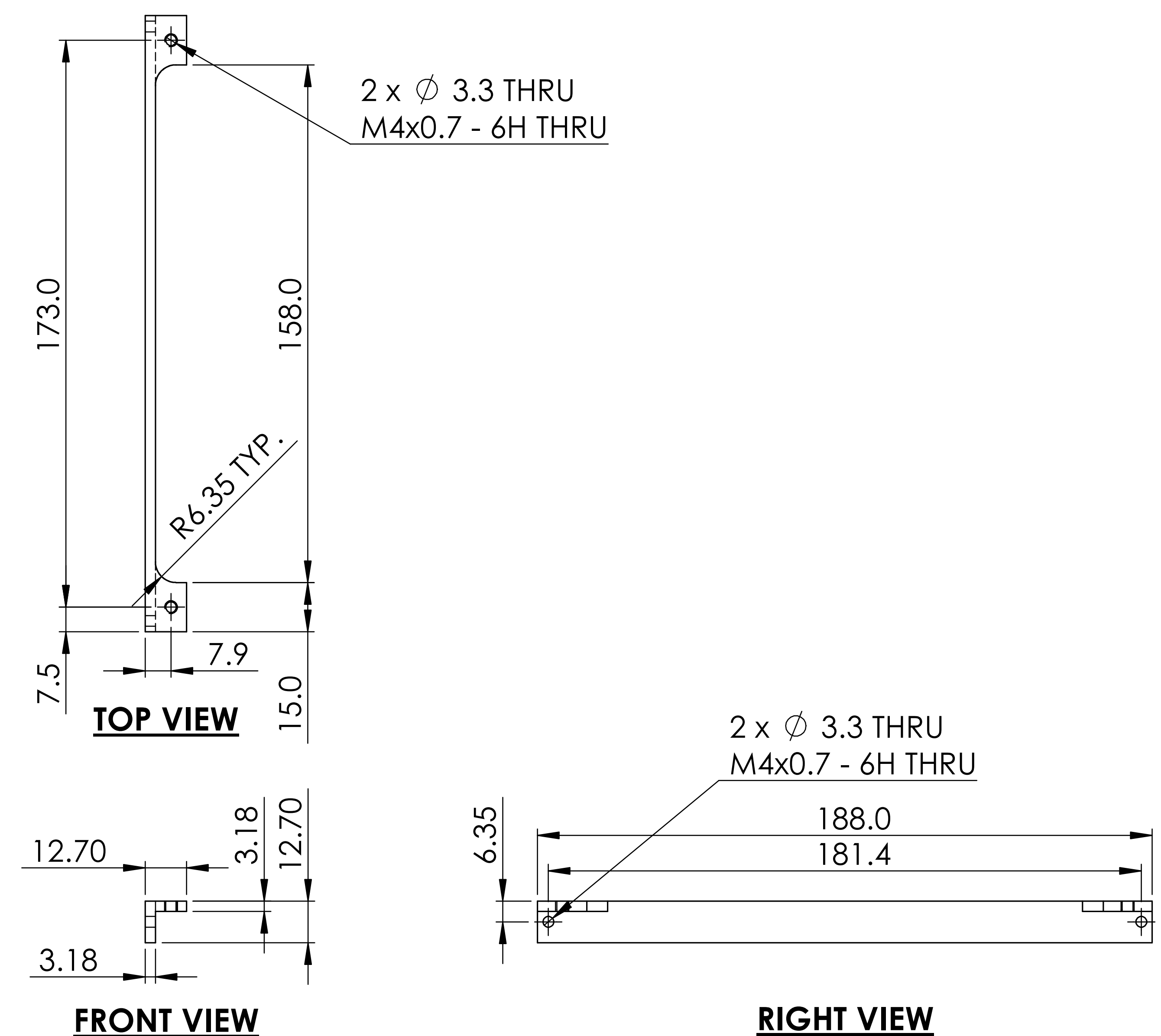
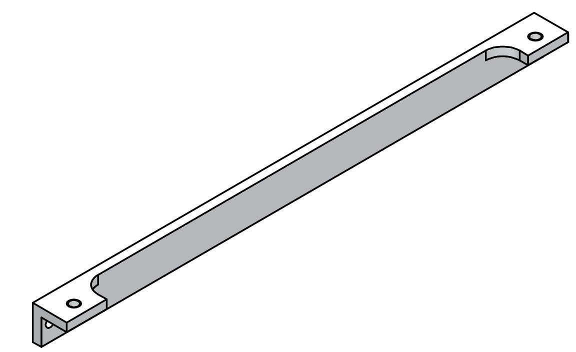
TITLE: **POWER ELECTRONICS PLATE**

PROJECT:	DWG NO.:			REV:
NEST	10211			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	1 OF 1	





SHEET NOTES:

1. THE WIDTH AND THICKNESS DIMENSIONS SHOWN ON THE FRONT VIEW ARE DRIVEN BY THE DIMENSIONS OF STOCK 1/2 INCH ALUMINUM ANGLE. PART MAY BE LEFT AT THE STOCK DIMENSIONS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

LASR
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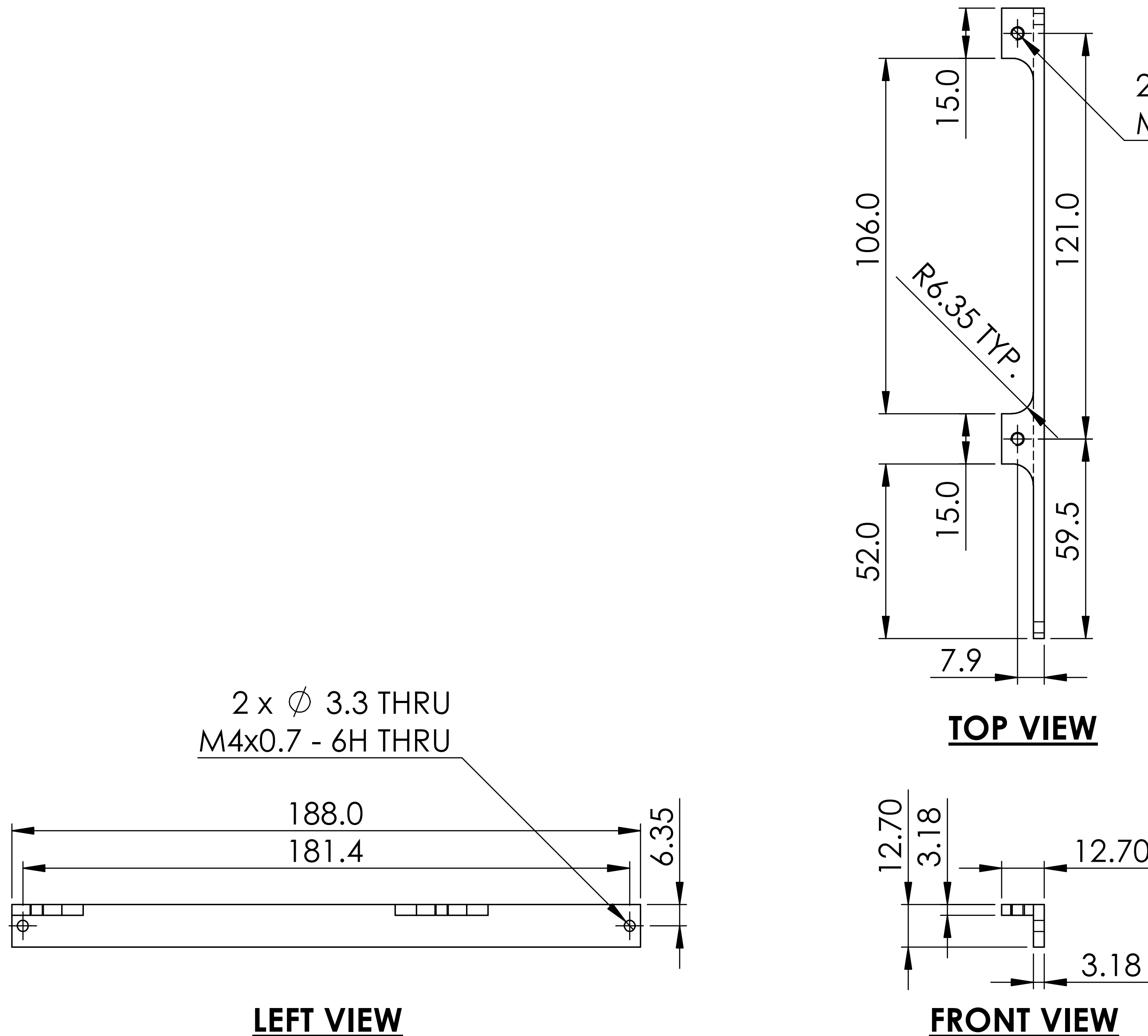
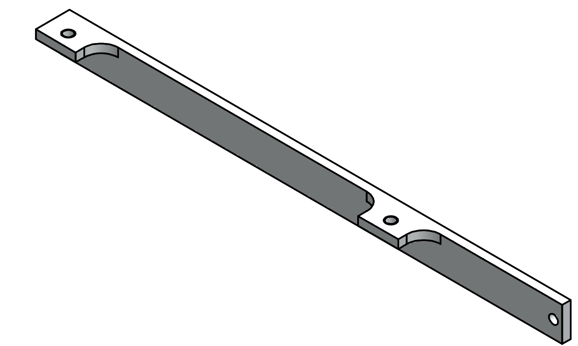
TEXAS A&M UNIVERSITY

TITLE: **LEFT POWER ELECTRONICS PLATE SUPPORT**

PROJECT:	DWG NO.:			REV:
NEST	10212			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	1 OF 1	





SHEET NOTES:

1. THE WIDTH AND THICKNESS DIMENSIONS SHOWN ON THE FRONT VIEW ARE DRIVEN BY THE DIMENSIONS OF STOCK 1/2 INCH ALUMINUM ANGLE. PART MAY BE LEFT AT THE STOCK DIMENSIONS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

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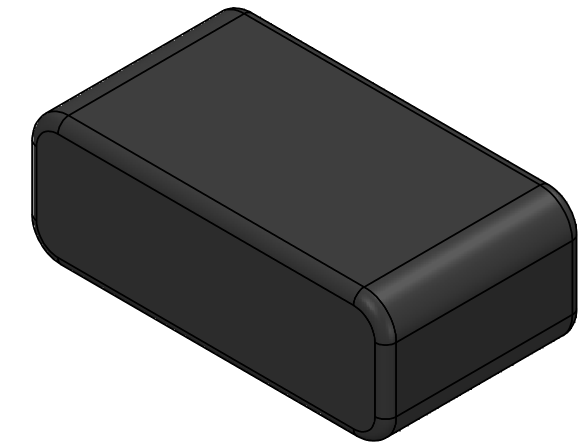
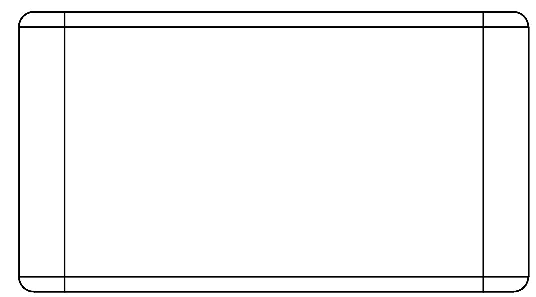
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

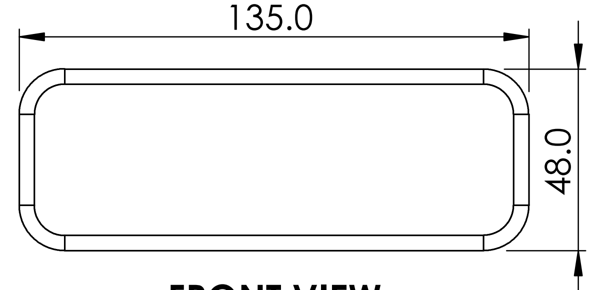
TITLE: **RIGHT POWER ELECTRONICS PLATE SUPPORT**

PROJECT:	DWG NO.:		REV:
NEST	10213		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1

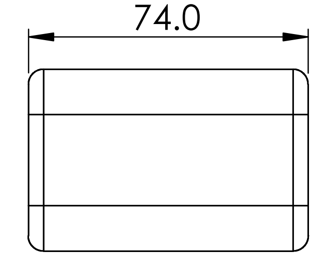




TOP VIEW



FRONT VIEW



RIGHT VIEW

SHEET NOTES:

1. A CAD MODEL FOR THIS PART WAS NOT AVAILABLE FORM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS CREATED USING EXTENT DIMENSIONS PROVIDED BY THE MANUFACTUER AND EDGE FILLETS WERE ESTIMATED BASED OFF OF VISUAL PROPORTIONS. THIS DRAWING SHALL NOT BE CONSIDERED REPRESENTATIVE OF THE ACTUAL PART AND IS PROVIDED FOR REFERENCE ONLY.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

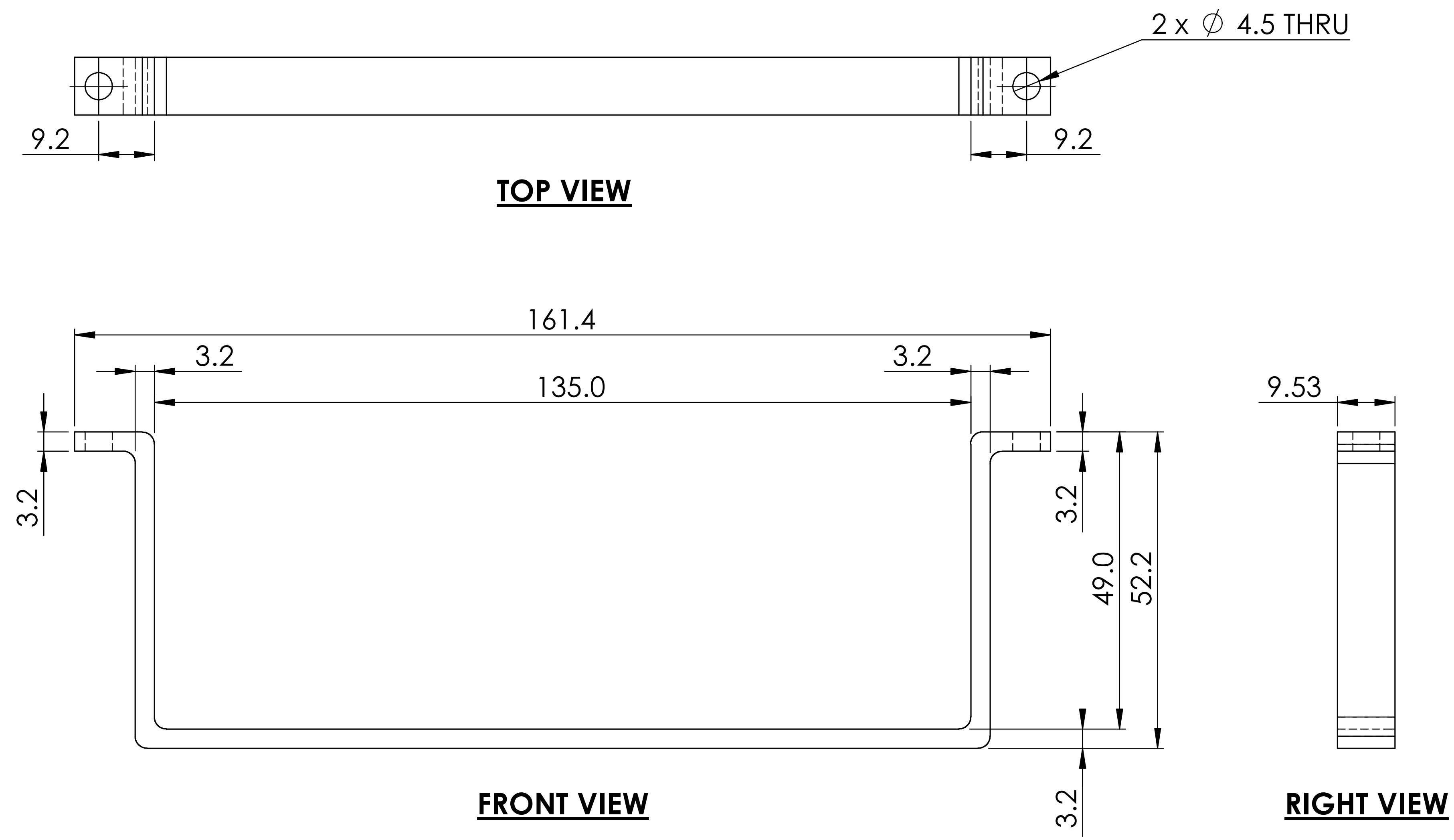
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

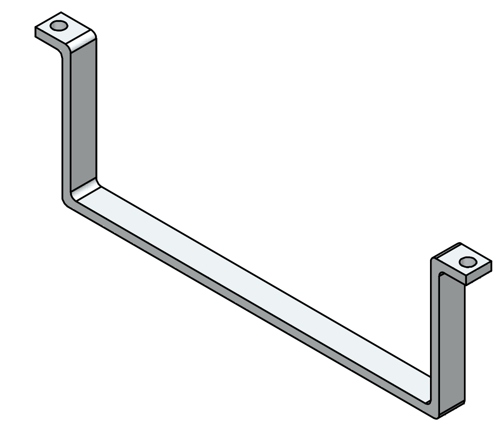
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **BATTERY - CUSTOM 25.2V 6700MAH LI-ION**

PROJECT:	DWG NO.:		REV:
NEST	**10214**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1





SHEET NOTES:

1. THE 9.53MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM SHEET. PART MAY BE LEFT AT THE STOCK THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

LASR
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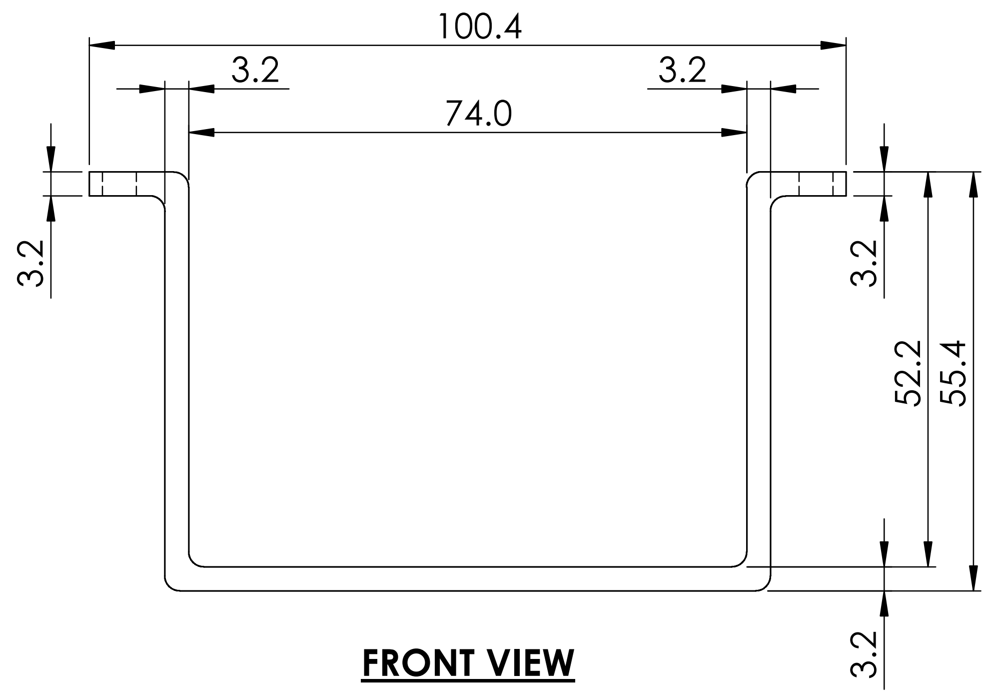
TEXAS A&M UNIVERSITY

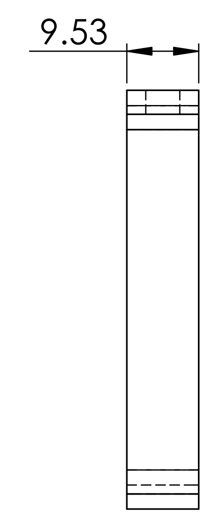
TITLE: **BATTERY SUPPORT BRACKET - LENGTH**

PROJECT:	DWG NO.:			REV:
NEST	10215			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:1	1 OF 1	

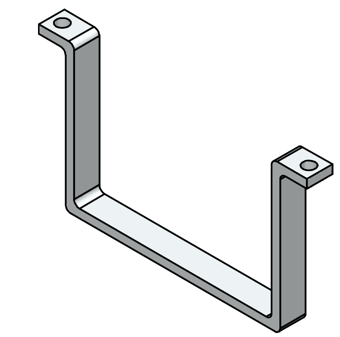
TOP VIEW



FRONT VIEW



RIGHT VIEW



SCALE 1 : 2

SHEET NOTES:

1. THE 9.53MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

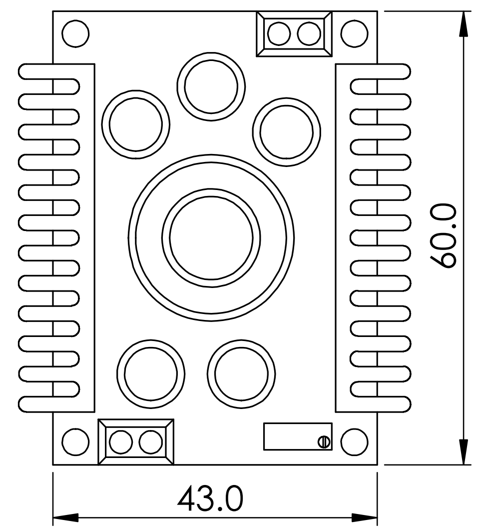
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

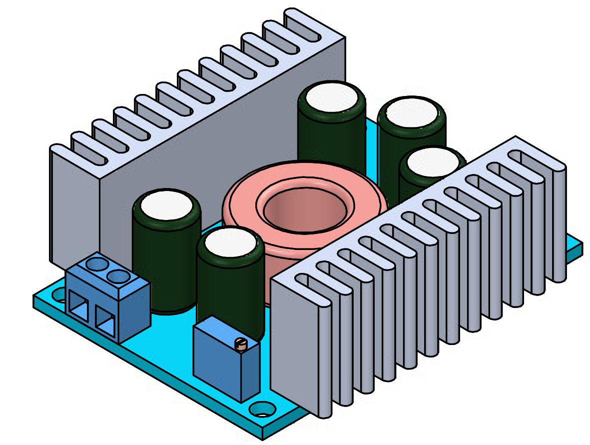
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

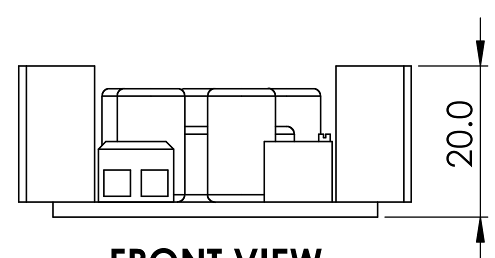
TITLE: **BATTERY SUPPORT BRACKET - WIDTH**

PROJECT:	DWG NO.:		REV:
NEST	10216		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1

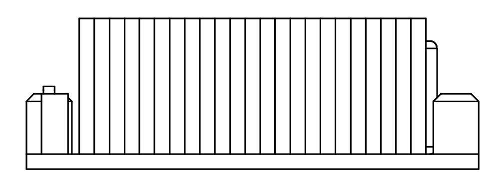


TOP VIEW





FRONT VIEW



RIGHT VIEW

SHEET NOTES:

1. A CAD MODEL FOR THIS PART WAS NOT AVAILABLE FROM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS CREATED USING EXTENT DIMENSIONS PROVIDED BY THE MANUFACTURER AND INTERIOR DIMENSIONS FOR COMPONENTS WERE ESTIMATED USING VISUAL PROPORTIONS FROM PART IMAGES. THEREFORE, THE DRAWING FOR THIS PART SHOULD NOT BE CONSIDERED ACCURATE AND IS PROVIDED FOR REFERENCE ONLY.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

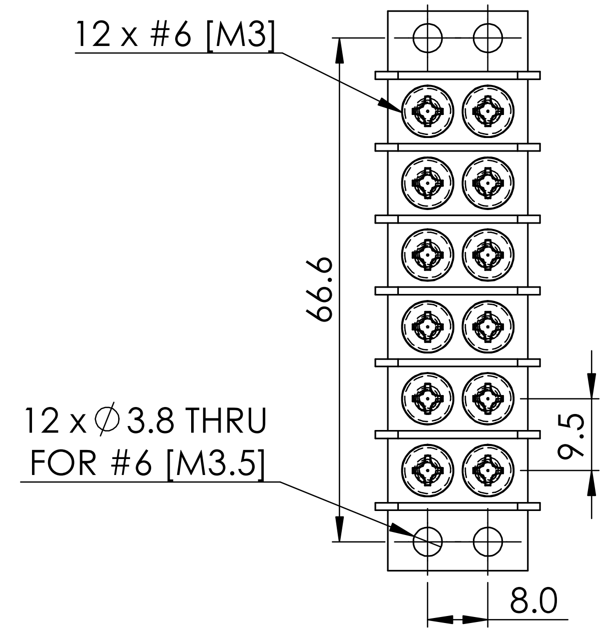
MATERIAL:

LASR

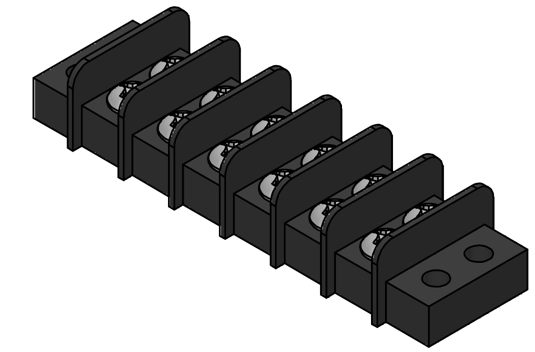
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

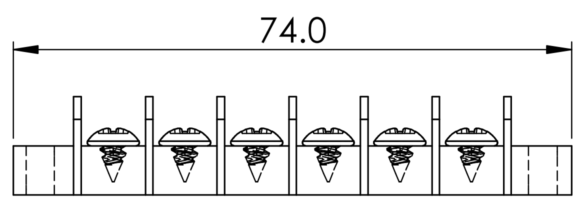
TITLE: **DROK DC STEP-DOWN CONVERTER**

PROJECT:	DWG NO.:		REV:
NEST	10217		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1

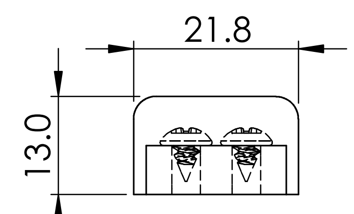


TOP VIEW





LEFT VIEW



FRONT VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

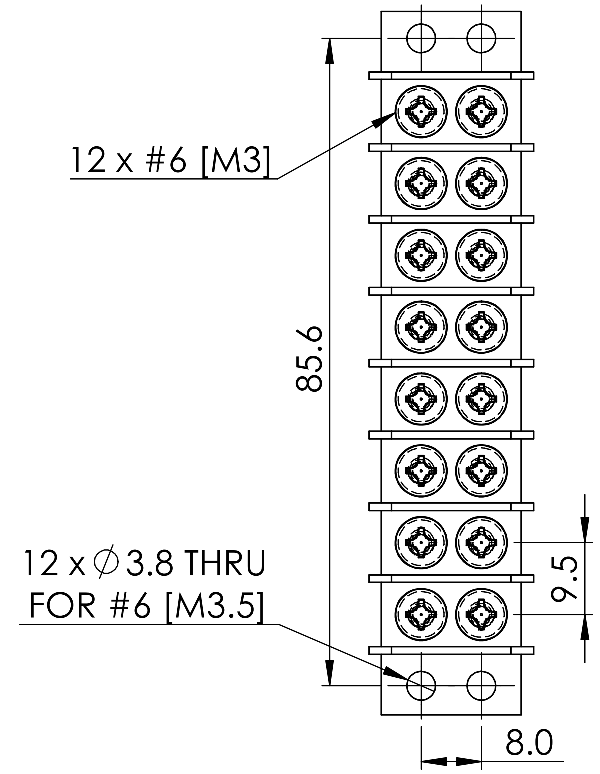
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

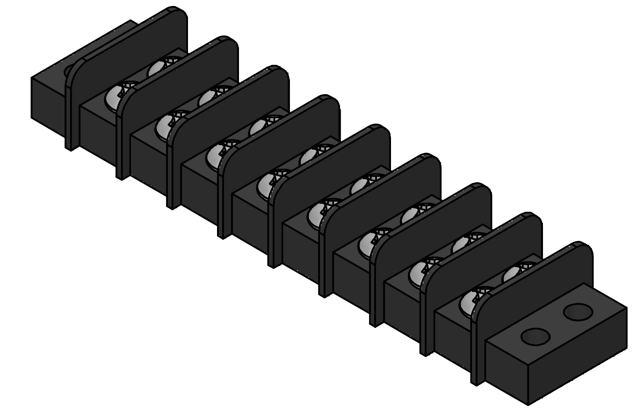
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

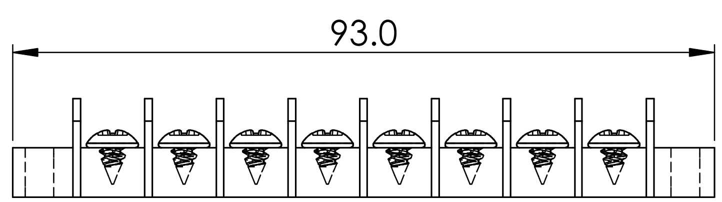
TITLE: **TERMINAL BLOCK - 6 POLE**

PROJECT:	DWG NO.:		REV:
NEST	**10218**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1

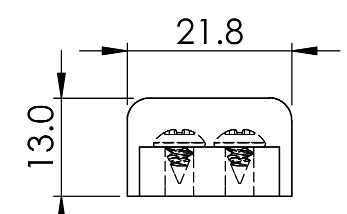


TOP VIEW





LEFT VIEW



FRONT VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

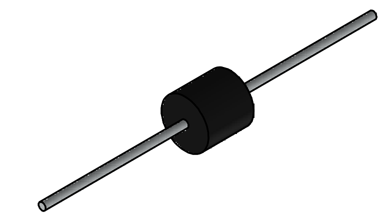
COMMENTS:

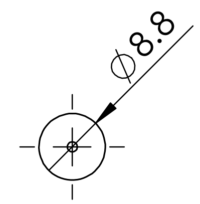
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

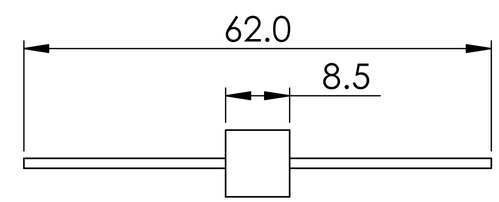
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **TERMINAL BLOCK - 8 POLE**			
PROJECT: NEST	DWG NO.: **10219**		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:1	SHEET: 1 OF 1





FRONT VIEW



SIDE VIEW

SHEET NOTES:

1. A CAD MODEL FOR THIS PART WAS NOT AVAILABLE FROM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS CREATED USING CALIPER MEASUREMENTS TAKEN OF A UNIT PURCHASED BY THE LASR LAB.
2. THE WIRE LEADS EXTENDING 62MM AS SHOW ON THE SIDE VIEW ARE TRIMMED APPROPRIATELY WHEN DIODE IS INSTALLED.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	2

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	AS MEASURED	A. SIMON

COMMENTS:

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

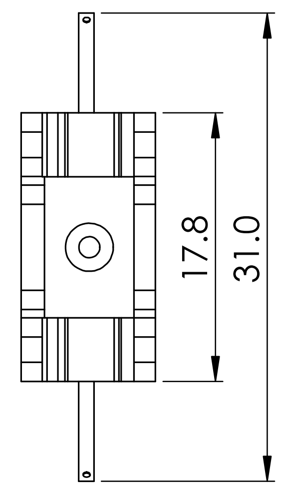
LASR

LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

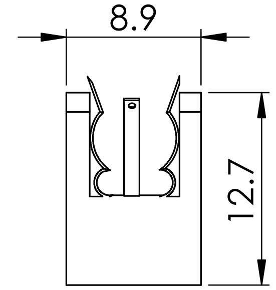
TITLE:

DIODE - 15A, 45VDC

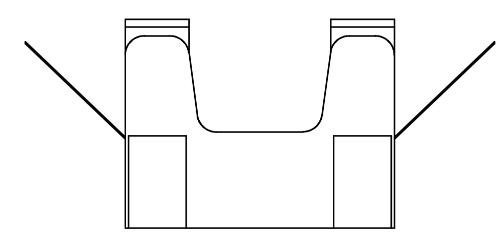
PROJECT:	DWG NO.:		REV:
NEST	**10220**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1



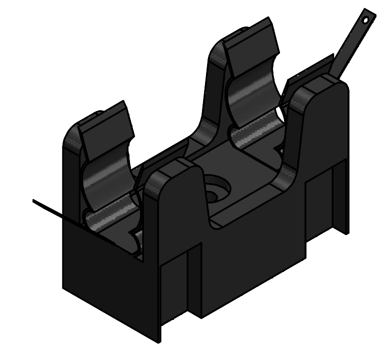
TOP VIEW



FRONT VIEW



RIGHT VIEW



ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	7

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

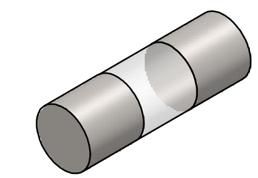
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

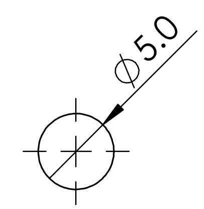
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

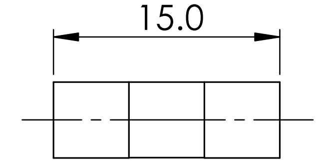
TITLE: **FUSE HOLDER, SOLDER TYPE - 5MM X 15MM**

PROJECT:	DWG NO.:		REV:
NEST	**10221**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	2:1	1 OF 1





FRONT VIEW



RIGHT VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10200	POWER ELECTRONICS PLATE ASSEMBLY	7

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	AS MANUFACTURED	A. SIMON

COMMENTS:

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

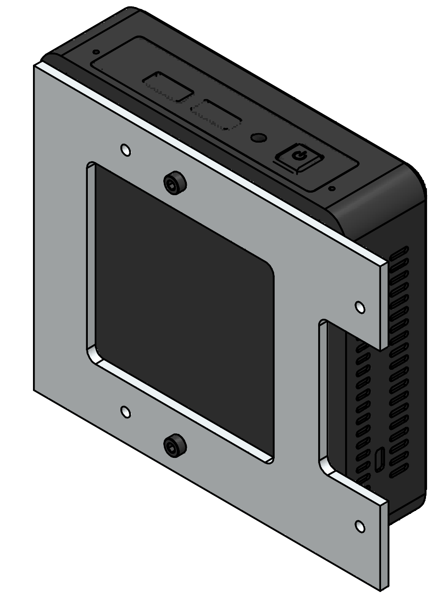
MATERIAL:

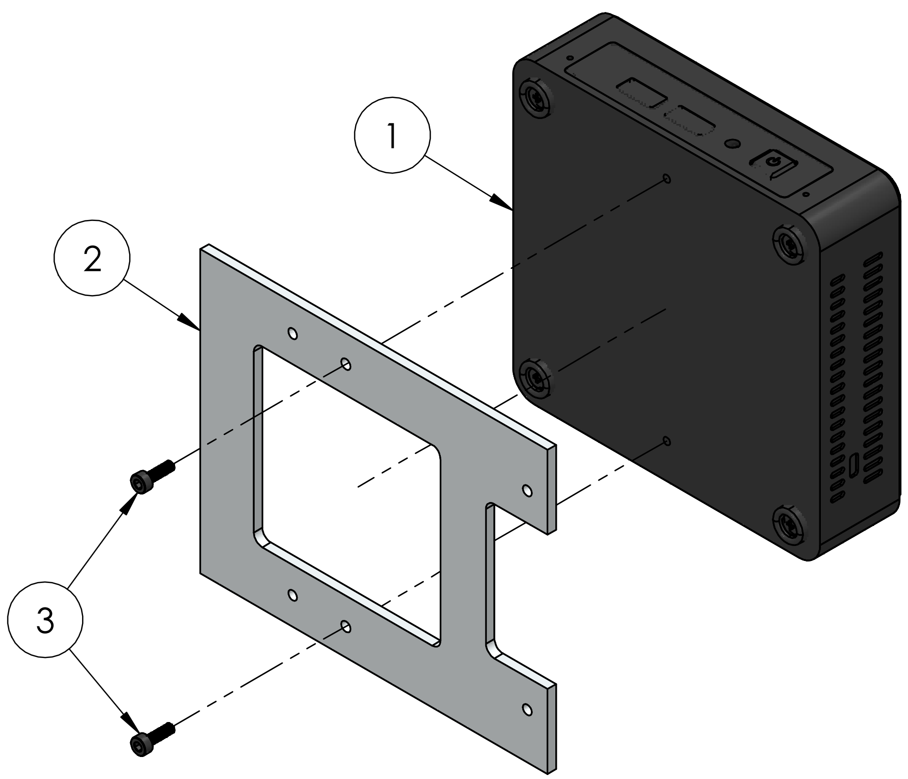
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
FUSE - 5MM X 15MM

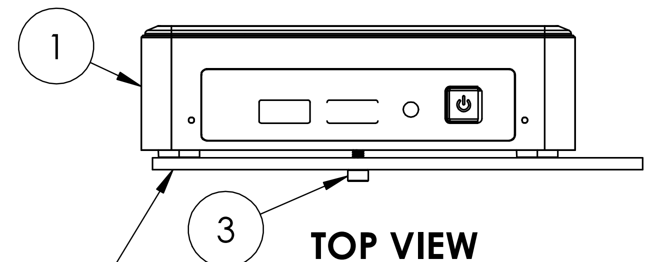
PROJECT:	DWG NO.:			REV:
NEST	**10222**			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	2:1	1 OF 1	

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10311	NUC COMPUTER	1
2	10312	NUC MOUNTING ADAPTER	1
3	10933	M3x0.5 - 6H 10MM SOCKET HEAD SCREW	2

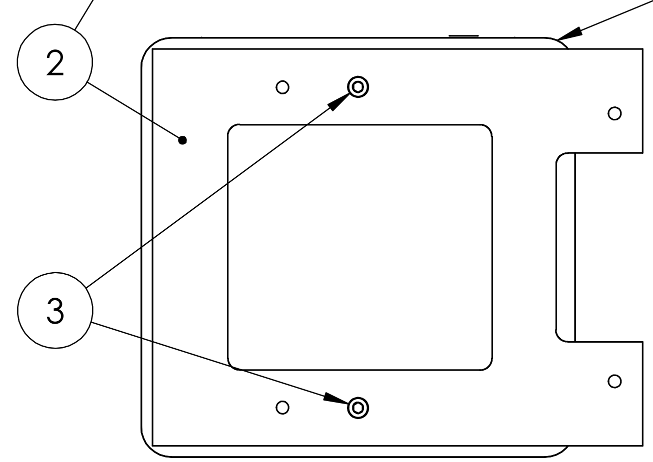




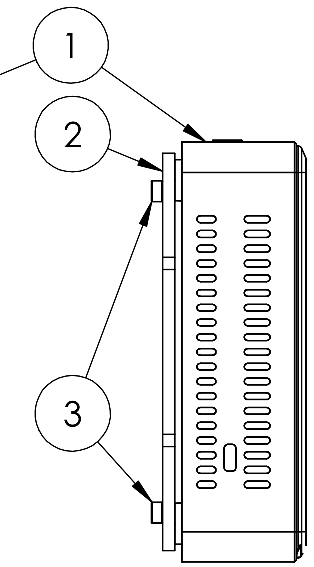
EXPLODED VIEW



TOP VIEW



FRONT VIEW



RIGHT VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

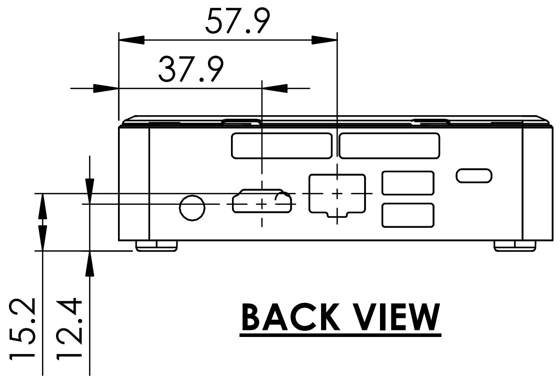
COMMENTS:

MATERIAL:

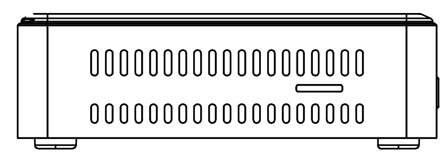
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NUC COMPUTER MOUNTING ASSEMBLY**

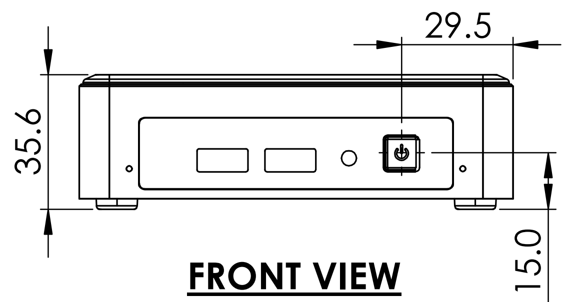
PROJECT:	DWG NO.:		REV:
NEST	10300		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1



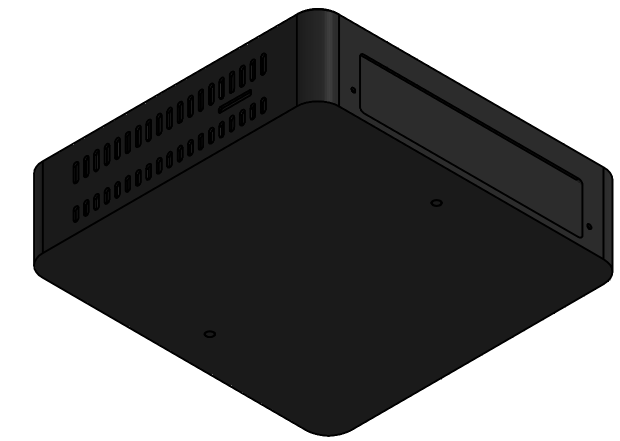
BACK VIEW

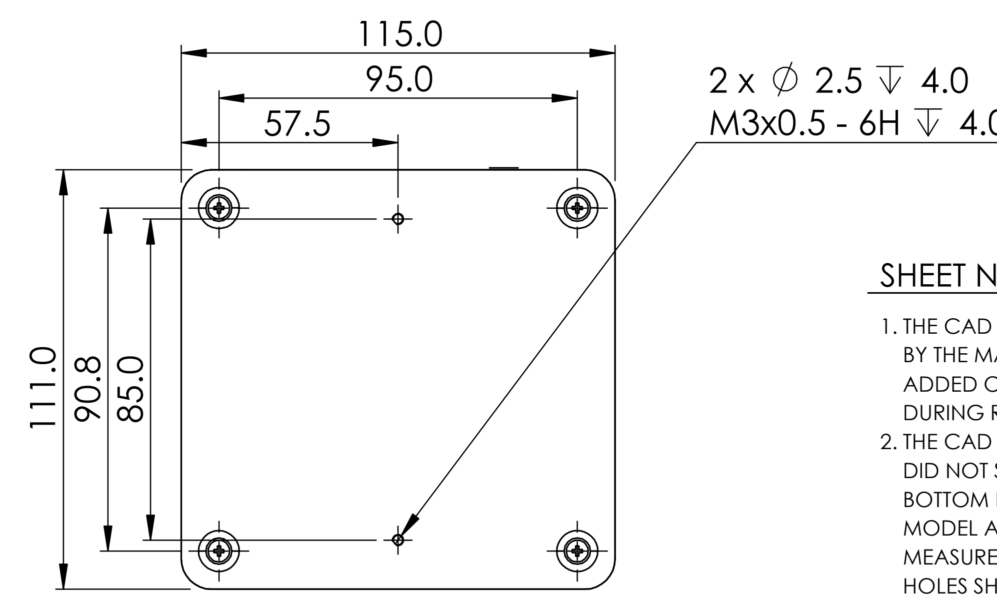


LEFT VIEW



FRONT VIEW





BOTTOM VIEW

SHEET NOTES:

1. THE CAD MODEL FOR THIS DRAWING WAS PROVIDED BY THE MANUFACTURER. DIMENSIONS HAVE BEEN ADDED ONLY FOR FEATURES USED BY AN OPERATOR DURING RUNTIME AND FOR MOUNTING.
2. THE CAD MODEL PROVIDED BY THE MANUFACTURER DID NOT SHOW THE (2) M3 HOLES PRESENT ON THE BOTTOM FACE. THESE HOLES WERE ADDED TO THE MODEL AND WERE LOCATED USING CALIPER MEASUREMENTS. THEREFORE, THE LOCATION OF THE HOLES SHALL BE CONSIDERED REASONABLY ACCURATE, BUT NOT PERFECT.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10300	NUC MOUNTING ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

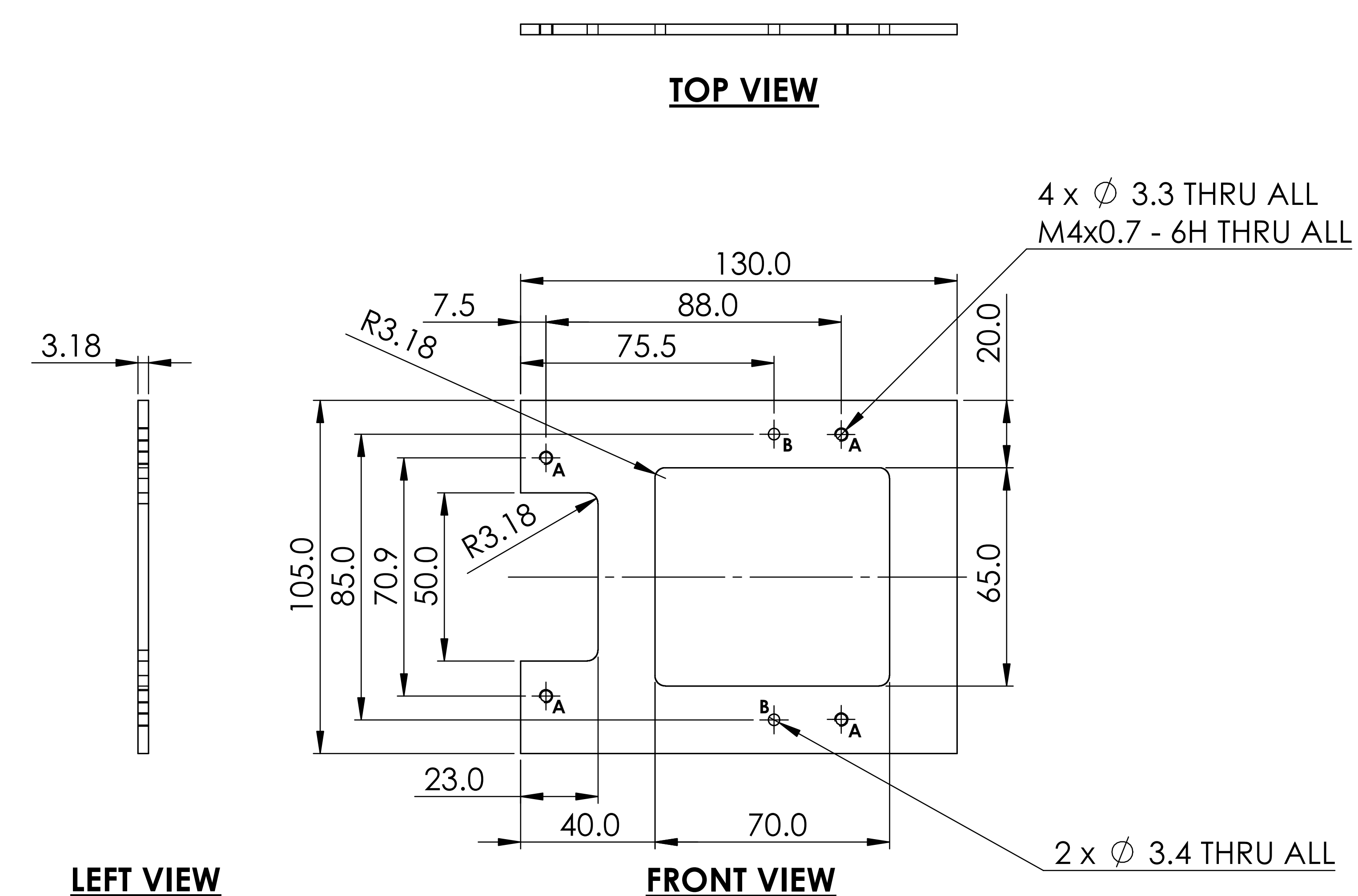
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

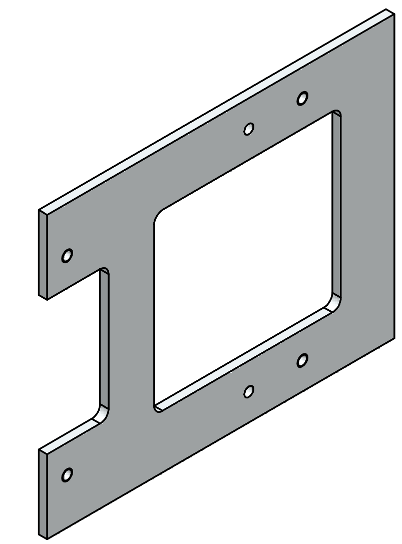
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
NUC COMPUTER

PROJECT:	DWG NO.:		REV:
NEST	**10311**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1





SHEET NOTES:

1. THE 3.18MM THICKNESS DIMENSION ON LEFT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ALUMINUM SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10300	NUC MOUNTING ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

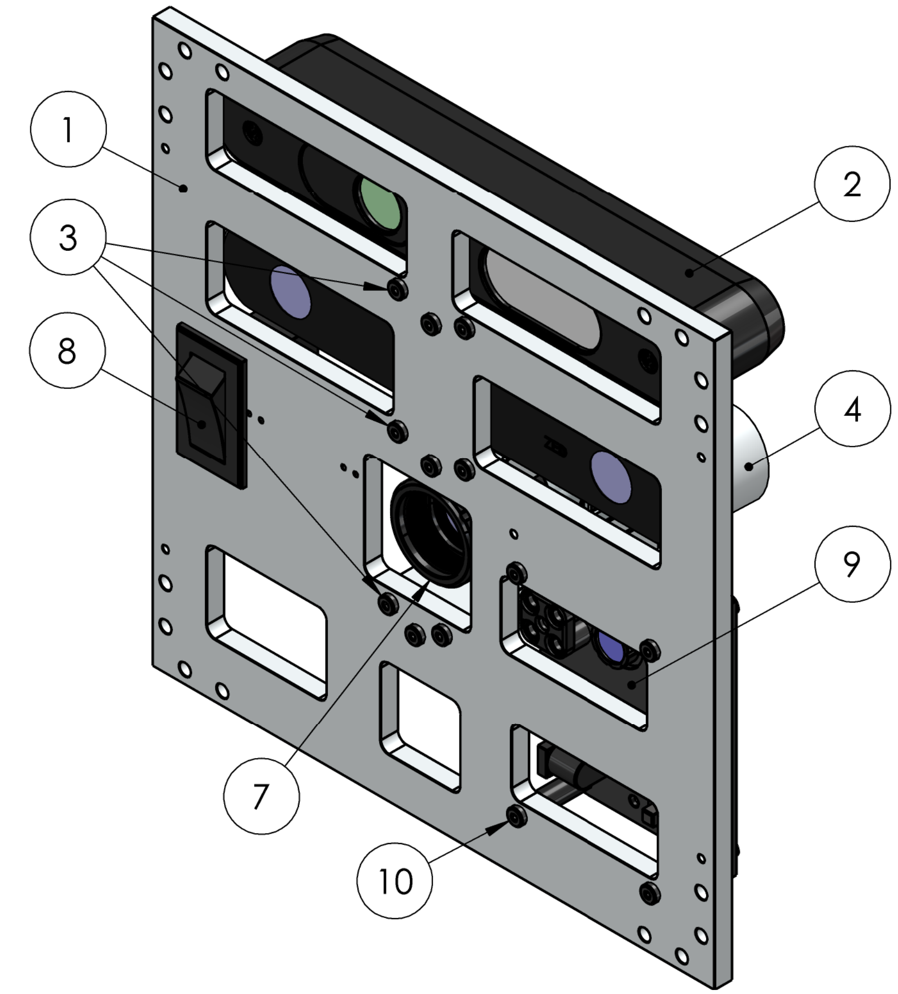
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **NUC MOUNTING ADAPTER**

PROJECT:	DWG NO.:			REV:
NEST	10312			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	1 OF 1	

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10401	SENSOR MOUNTING PLATE	1
2	10430	XTION CAMERA MOUNTING ASSEMBLY	1
3	10935	M3x0.5 12MM LOW PROFILE SOCKET HEAD SCREW	9
4	10410	ZED CAMERA MOUNTING ASSEMBLY	1
5	10451	VN-100 RUGGED IMU	1
6	10912	M2x0.4 5MM SOCKET HEAD SCREW	2
7	10420	ACA1300 CAMERA MOUNTING ASSEMBLY	1
8	10711	SPST ROCKER SWITCH	1
9	10441	OPT8241-CDK-EVM LIDAR MODULE	1
10	10937	M3x0.5 30MM LOW PROFILE SOCKET HEAD SCREW	4
11	10891	0.25IN OD 1/4IN NYLON SPACER	2
12	10971	M3 WASHER	6
13	10981	M3x0.5 HEX NUT	4
14	10893	0.25IN OD 11/16IN NYLON SPACER	2



ISOMETRIC VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

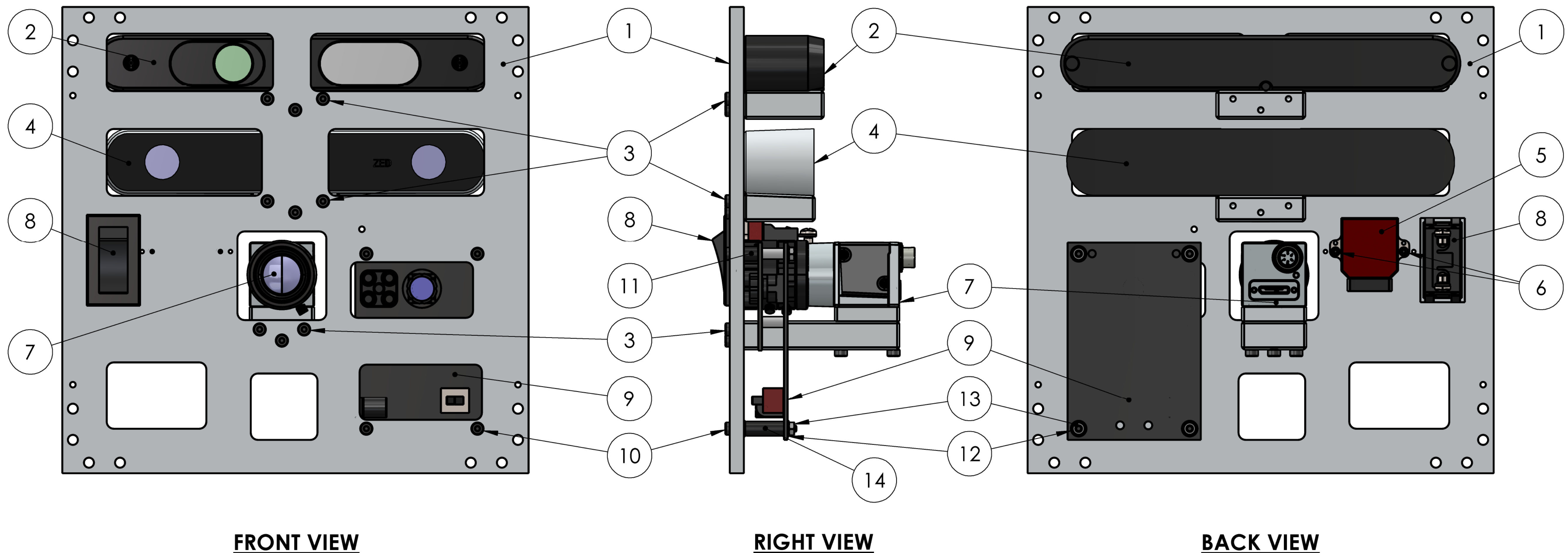
COMMENTS:

MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SENSOR ARRAY ASSEMBLY**

PROJECT:	DWG NO.:		REV:
NEST	10400		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 4



ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

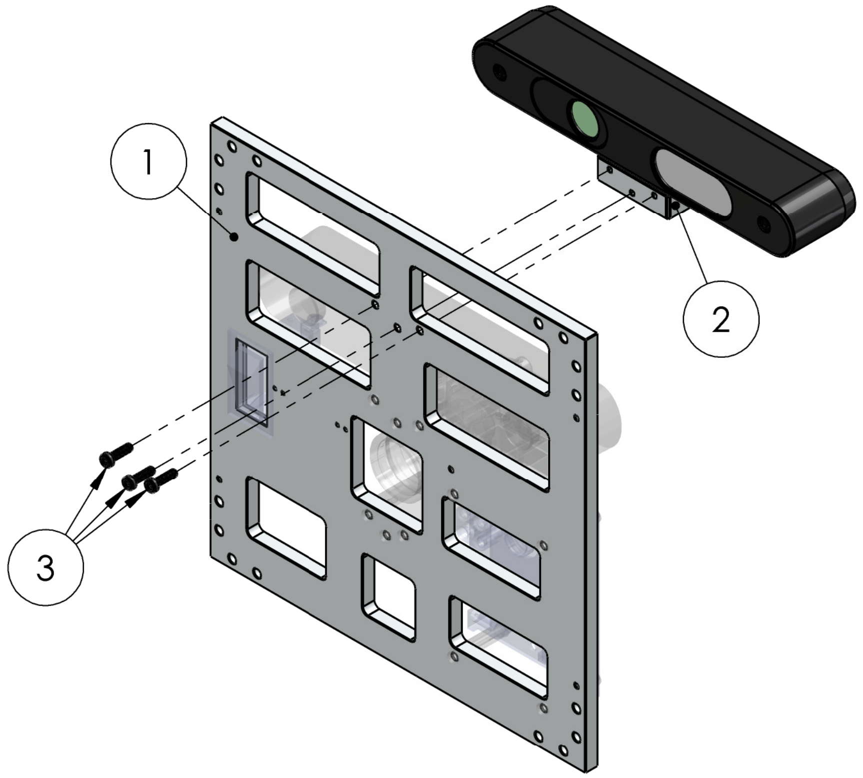
COMMENTS:

MATERIAL:

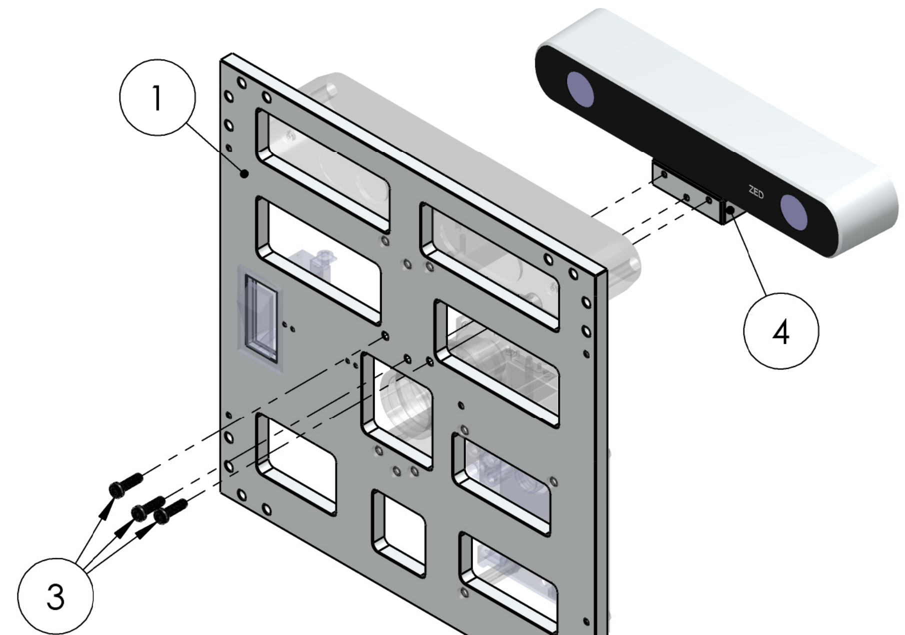
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SENSOR ARRAY ASSEMBLY**

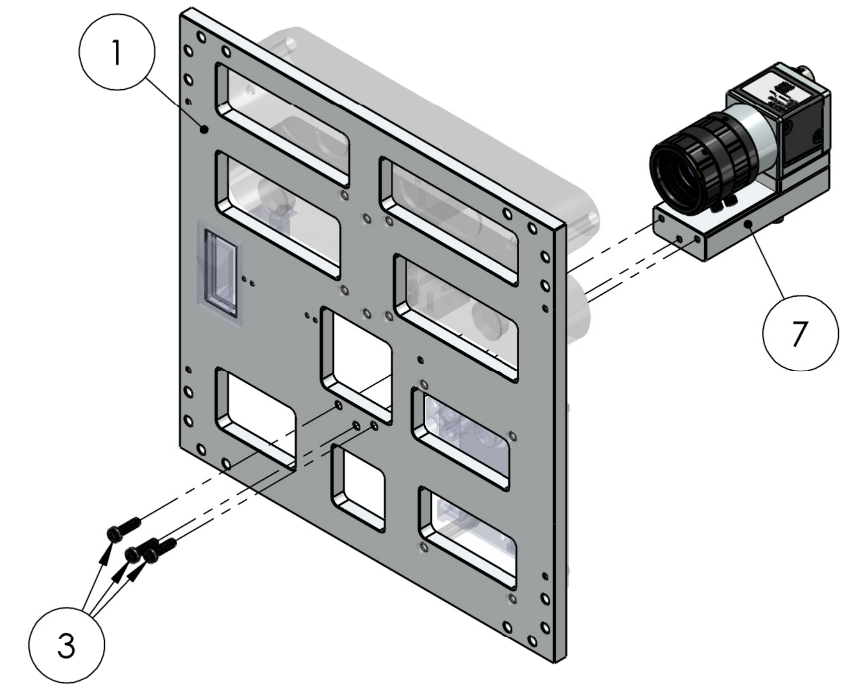
PROJECT:	DWG NO.:		REV:
NEST	10400		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 2 OF 4



PARTIAL EXPLODED VIEW
XTION CAMERA DETAIL



PARTIAL EXPLODED VIEW
ZED CAMERA DETAIL



PARTIAL EXPLODED VIEW
ACA1300 CAMERA DETAIL

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

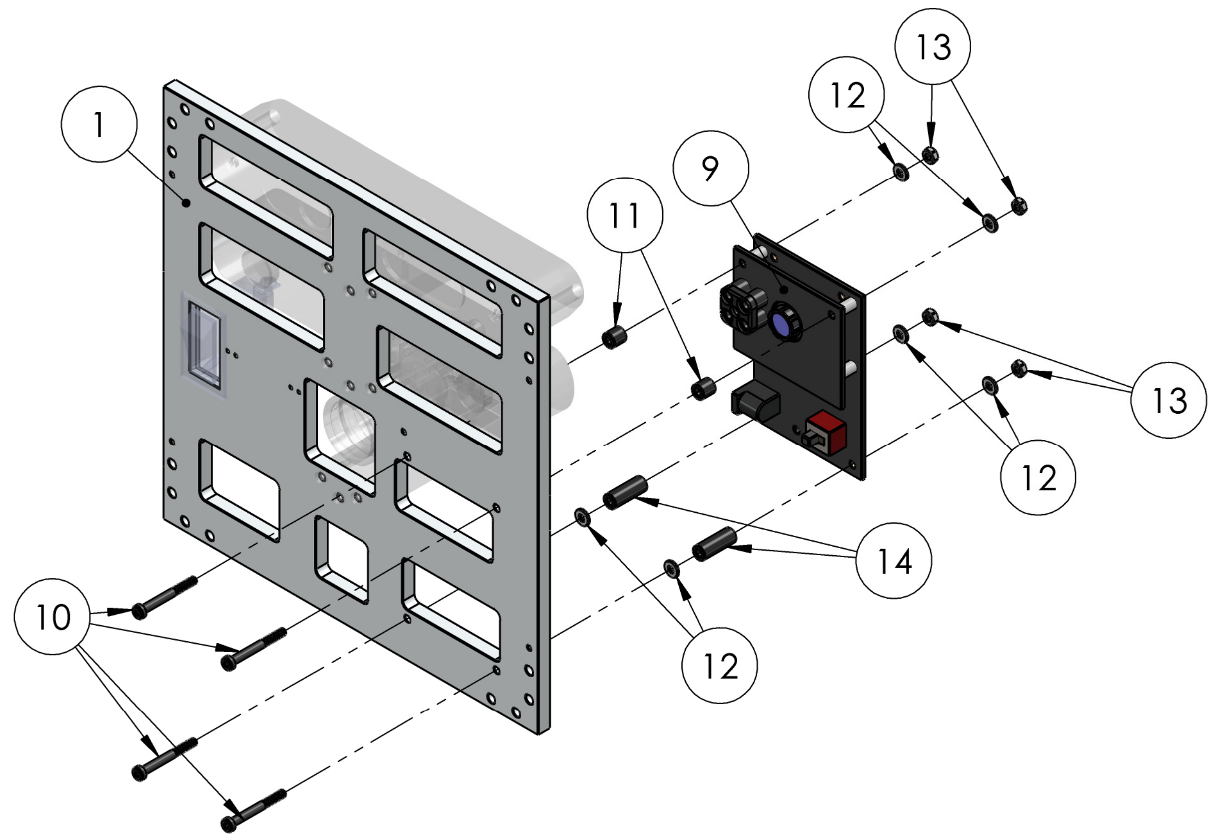
COMMENTS:

MATERIAL:

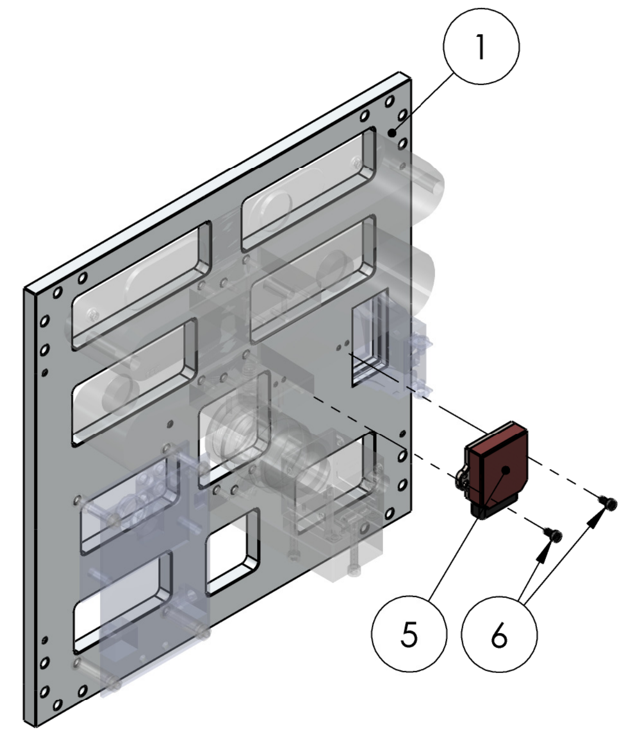
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SENSOR ARRAY ASSEMBLY**

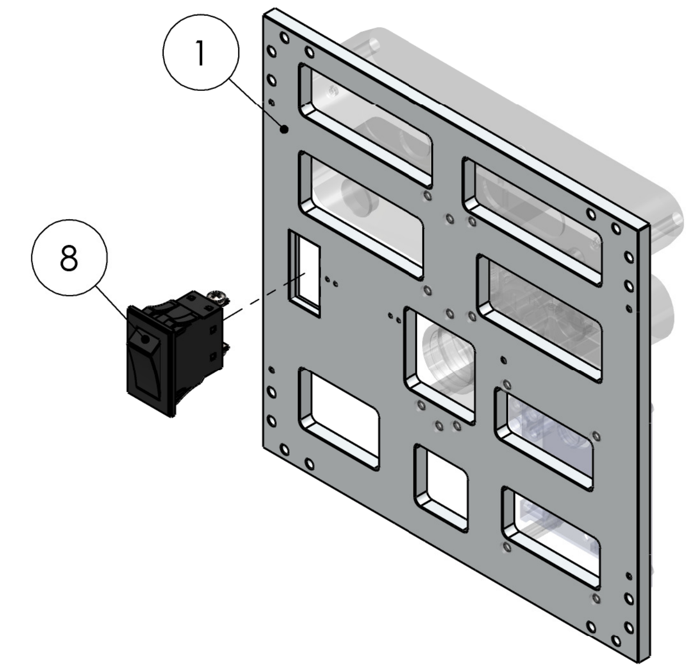
PROJECT:	DWG NO.:		REV:
NEST	10400		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:3	3 OF 4



PARTIAL EXPLODED VIEW
OPT8241 LIDAR DETAIL



PARTIAL EXPLODED VIEW
VN-100 RUGGED DETAIL



PARTIAL EXPLODED VIEW
SPST SWITCH DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

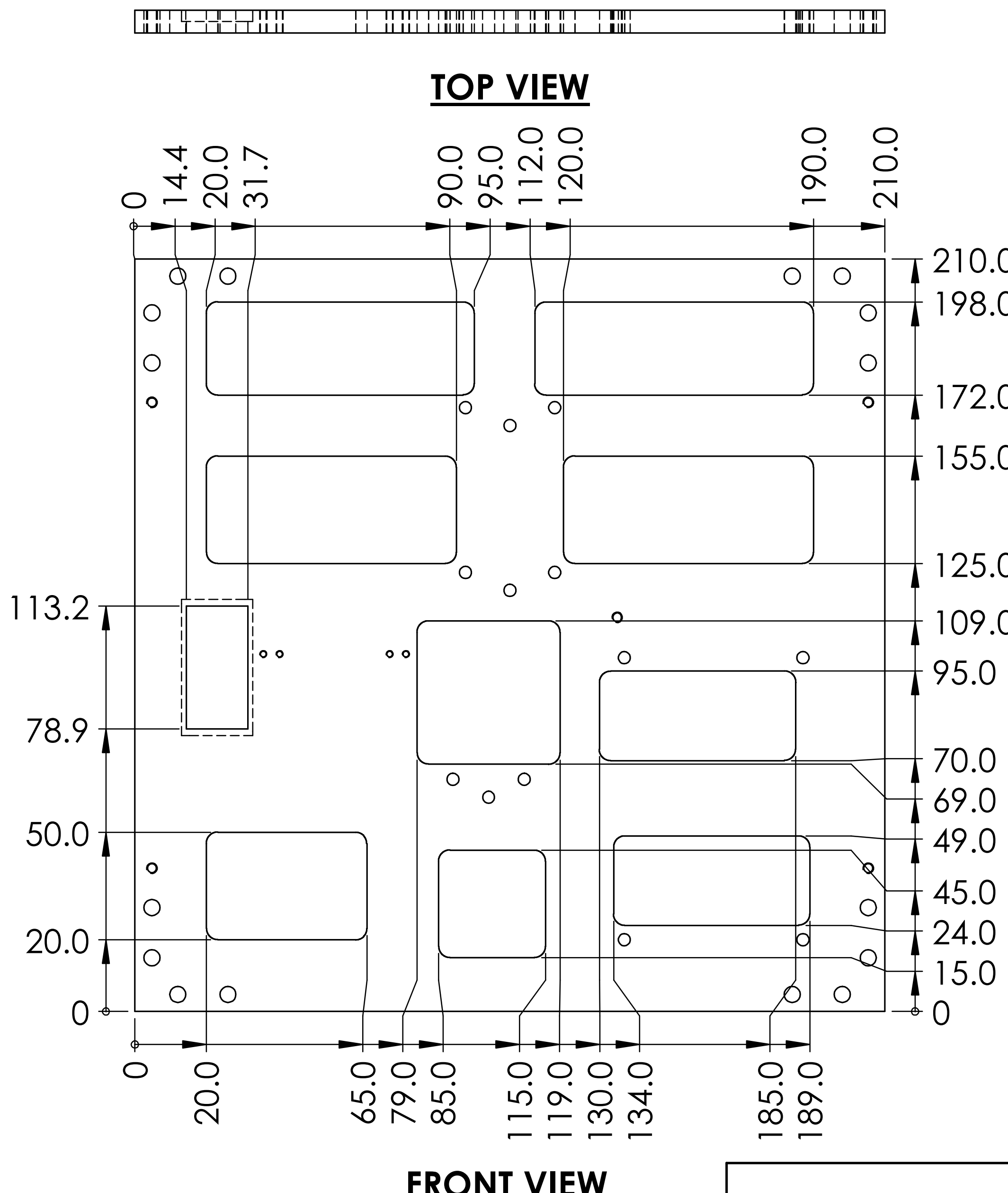
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

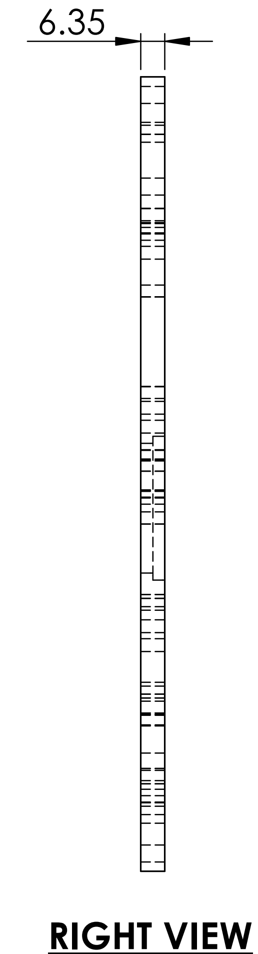
COMMENTS:

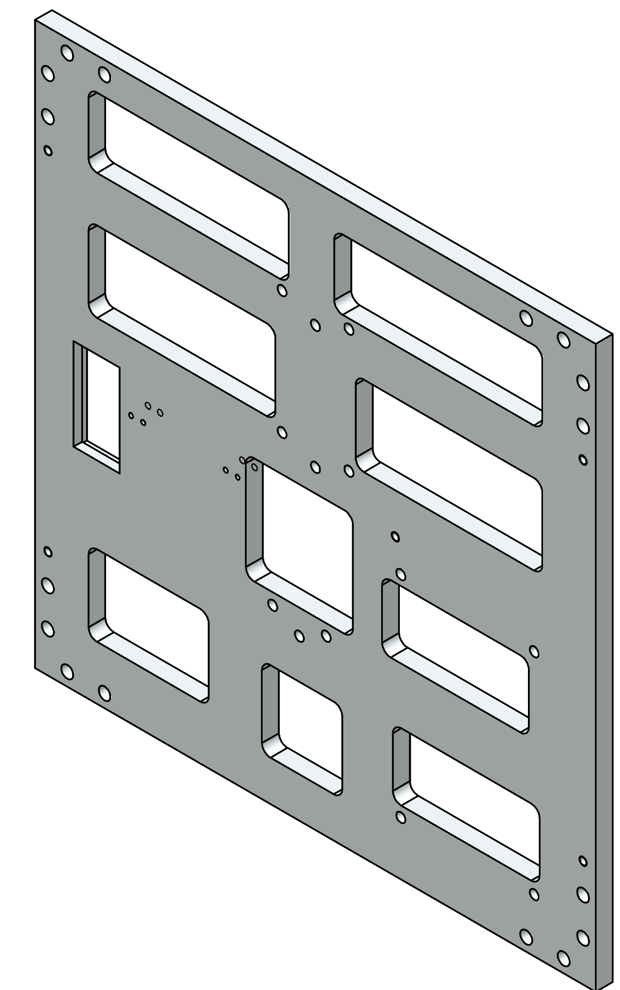
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: SENSOR ARRAY ASSEMBLY			
PROJECT: NEST	DWG NO.: 10400		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:3	SHEET: 4 OF 4







SHEET NOTES:

1. THE 6.35MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 3/8 INCH ALUMINUM PLATE. PART MAY BE LEFT AT THE STOCK PLATE THICKNESS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

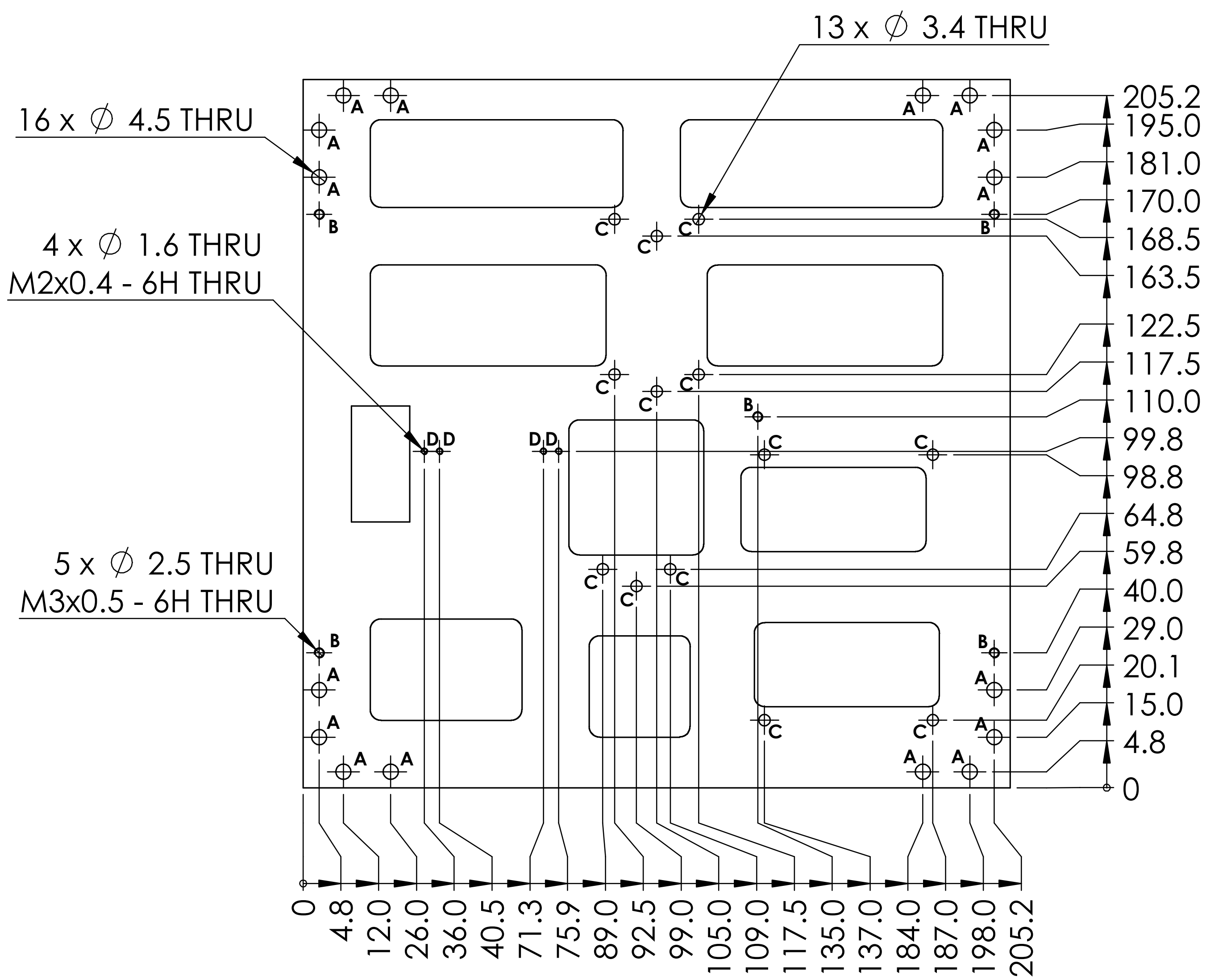
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

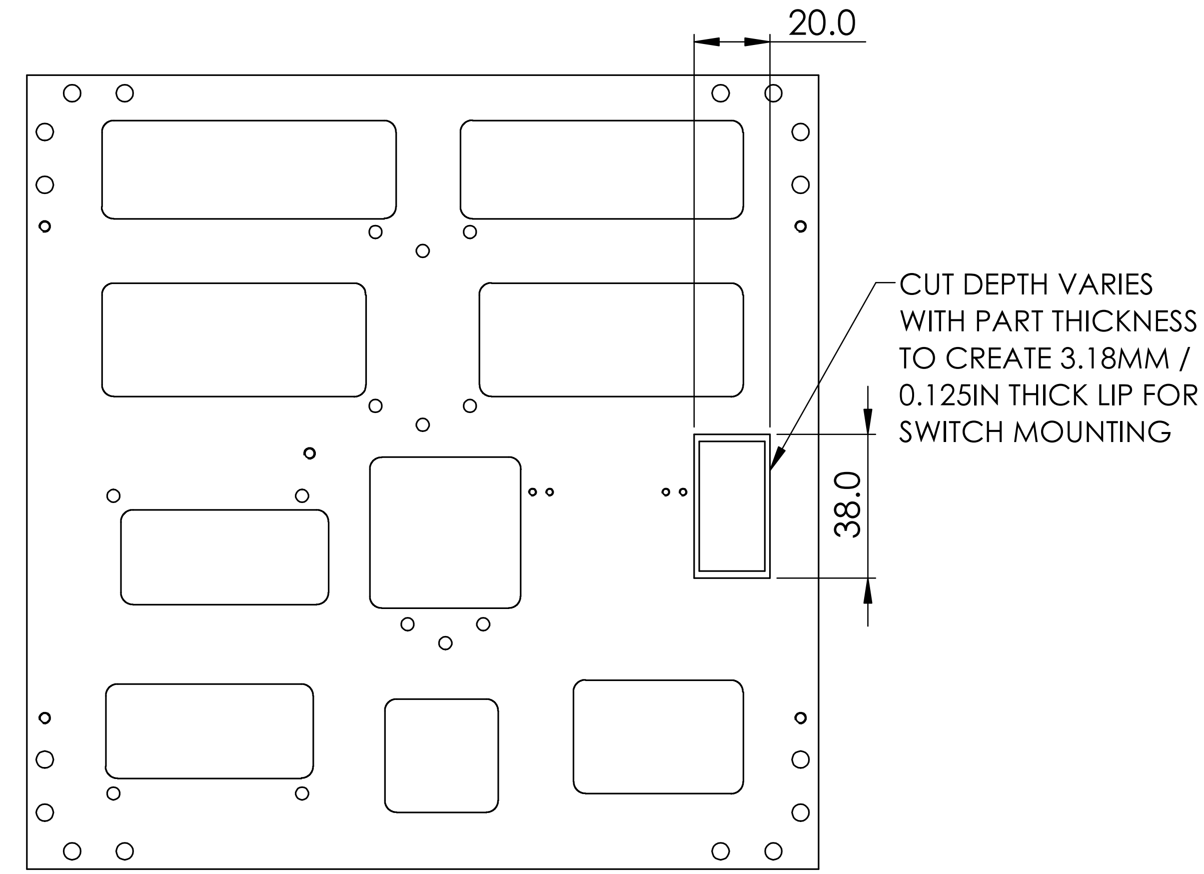
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SENSOR MOUNTING PLATE**

PROJECT:	DWG NO.:			REV:
NEST	10401			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	1 OF 2	



FRONT VIEW - HOLE DTAIL



BACK VIEW - SWITCH CUTOUT DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

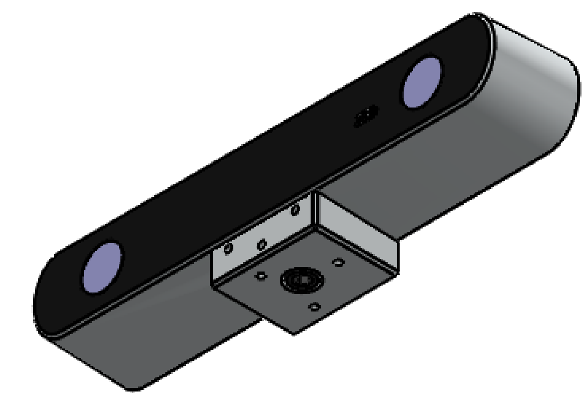
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

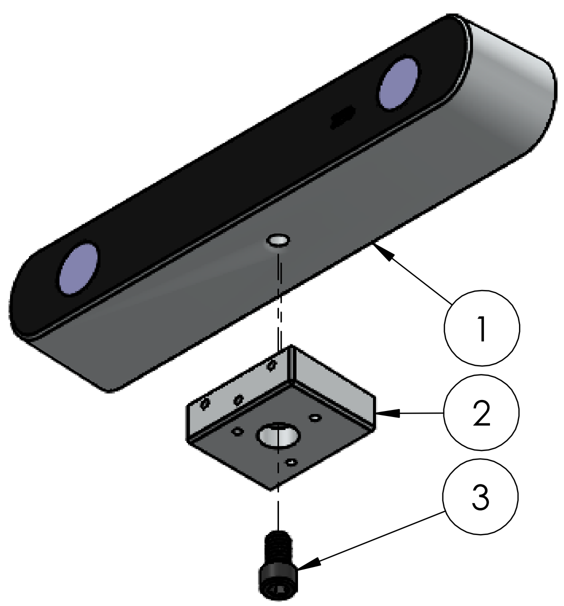
TITLE: **SENSOR MOUNTING PLATE**

PROJECT:	DWG NO.:	REV:
NEST	10401	0

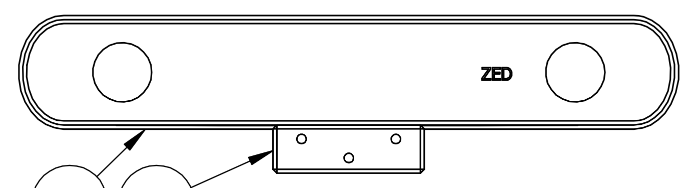
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	2 OF 2

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10411	ZED CAMERA	1
2	10412	ZED MOUNTING ADAPTER	1
3	10821	1/4"-20 UNC 7/16" SOCKET HEAD SCREW	1

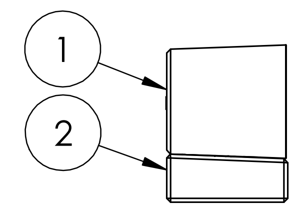




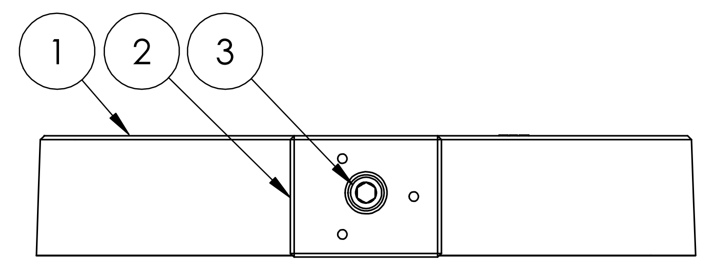
EXPLODED VIEW



FRONT VIEW



RIGHT VIEW



BOTTOM VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

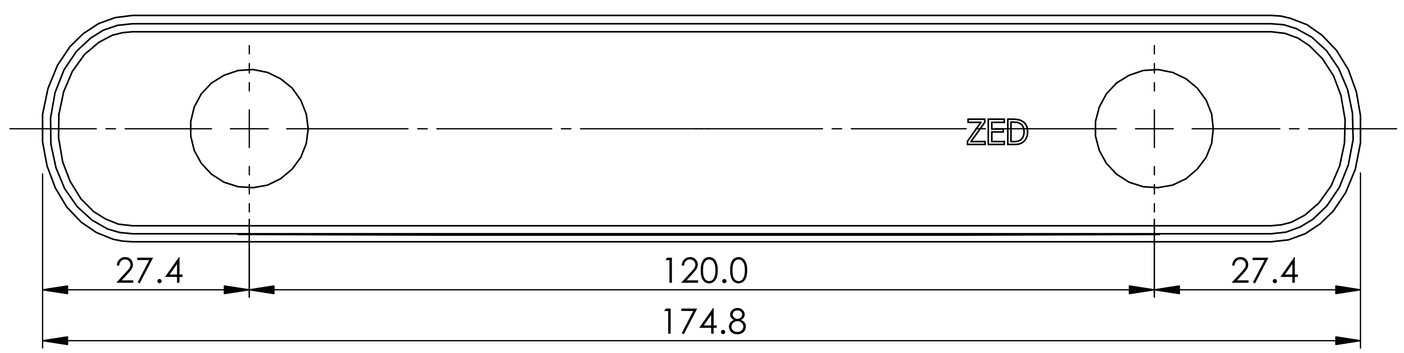
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

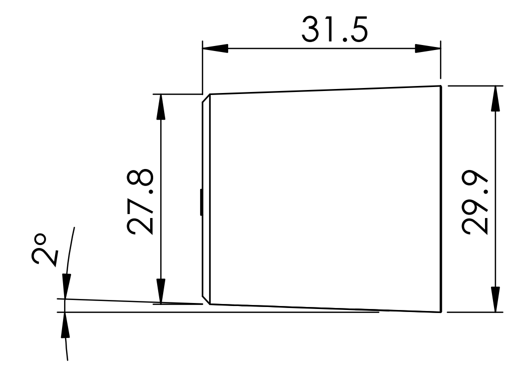
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

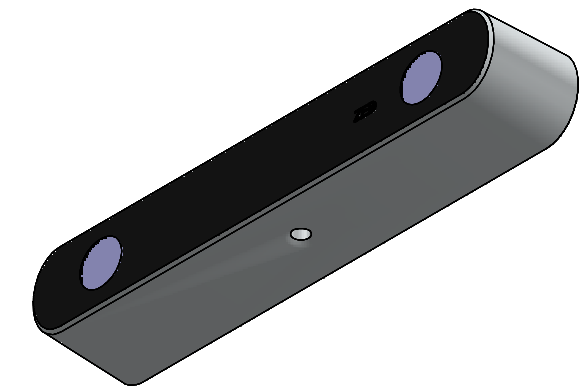
TITLE: ZED CAMERA MOUNTING ASSEMBLY			
PROJECT: NEST	DWG NO.: 10410		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 1 OF 1



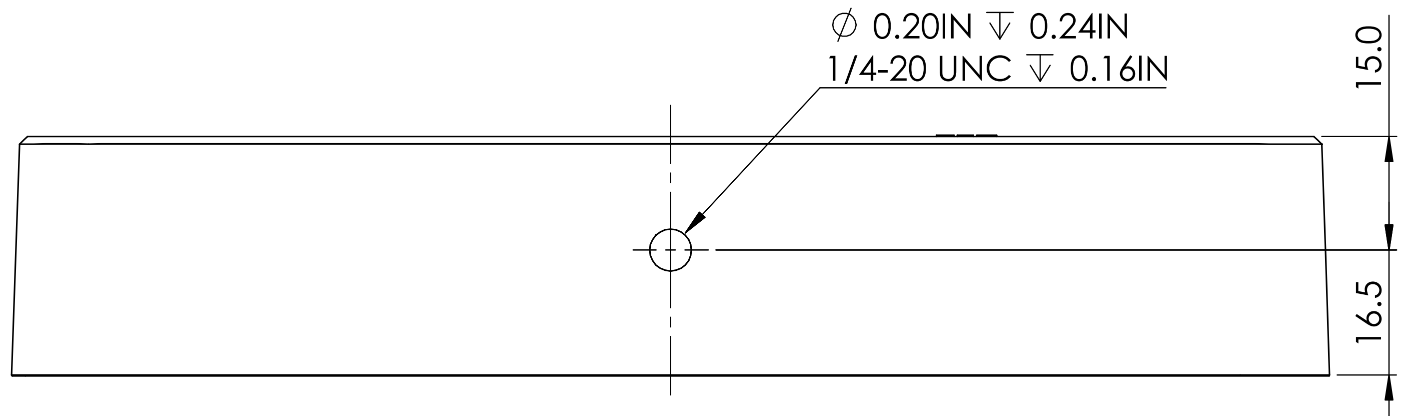
FRONT VIEW



RIGHT VIEW



SCALE 1:2



BOTTOM VIEW

SHEET NOTES:

1. THE DEPTH OF THE 1/4-20 HOLE CALLOUT ON BOTTOM VIEW WAS NOT AVAILABLE FROM THE MANUFACTURER AND WAS ESTIMATED. PLEASE CONTACT THE MANUFACTUER FOR ACCURATE TAP DEPTH.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10410	ZED CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

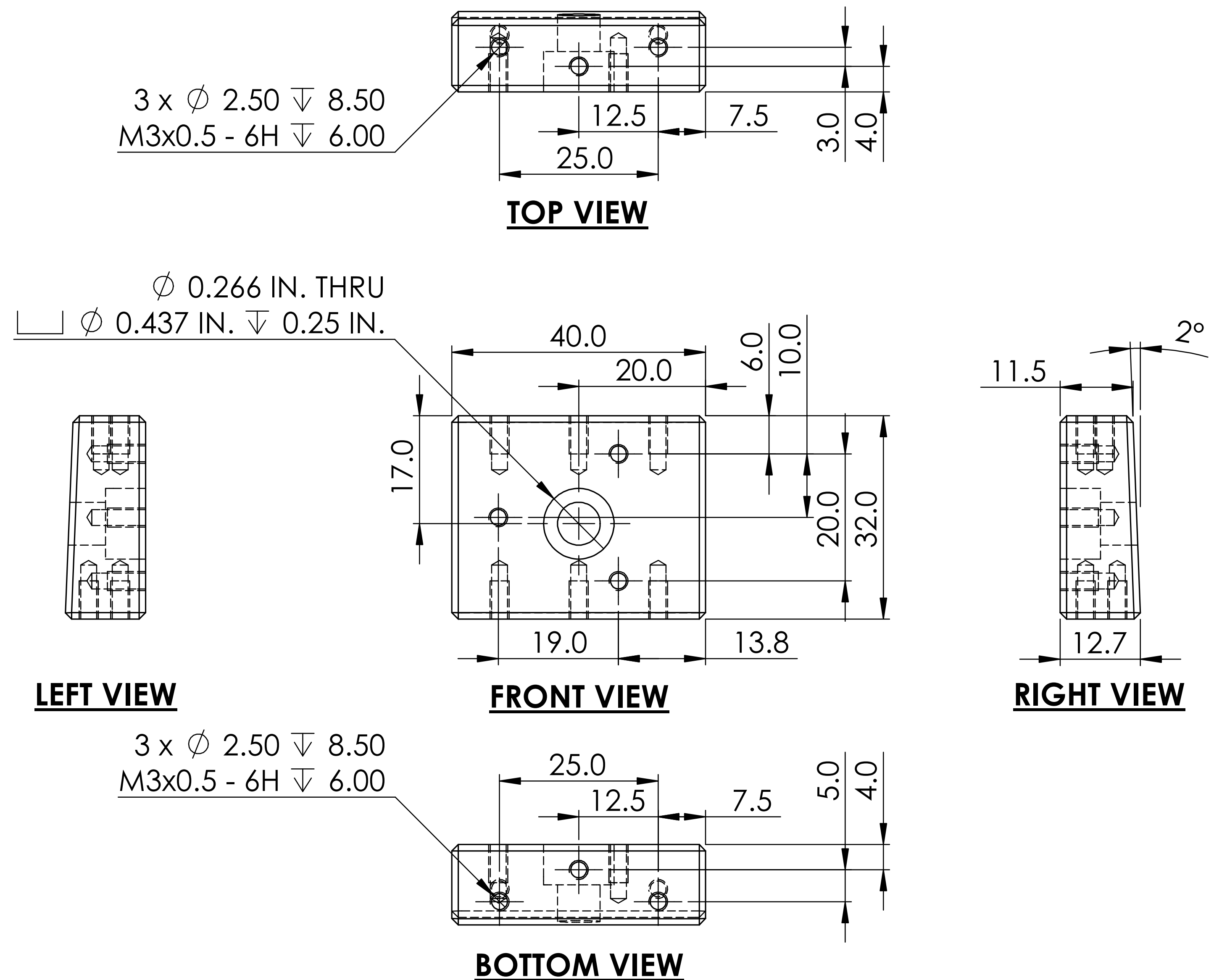
LASR

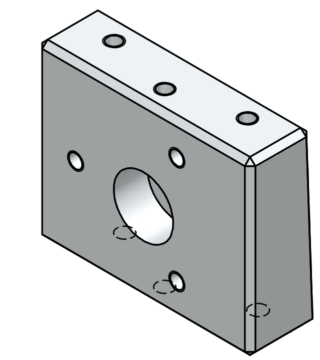
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:

ZED CAMERA

PROJECT:	DWG NO.:		REV:
NEST	**10411**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1





SHEET NOTES:

1. THE 2 DEGREE DRAFT SHOWN ON RIGHT VIEW MATCHES THE DRAFT ON ZED CAMERA HOUSING.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10410	ZED CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

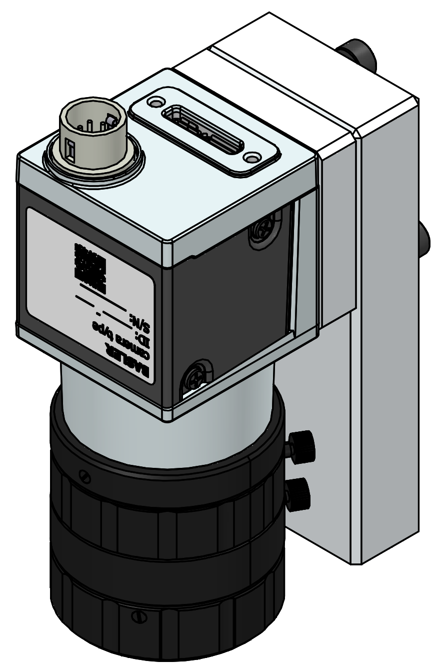
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

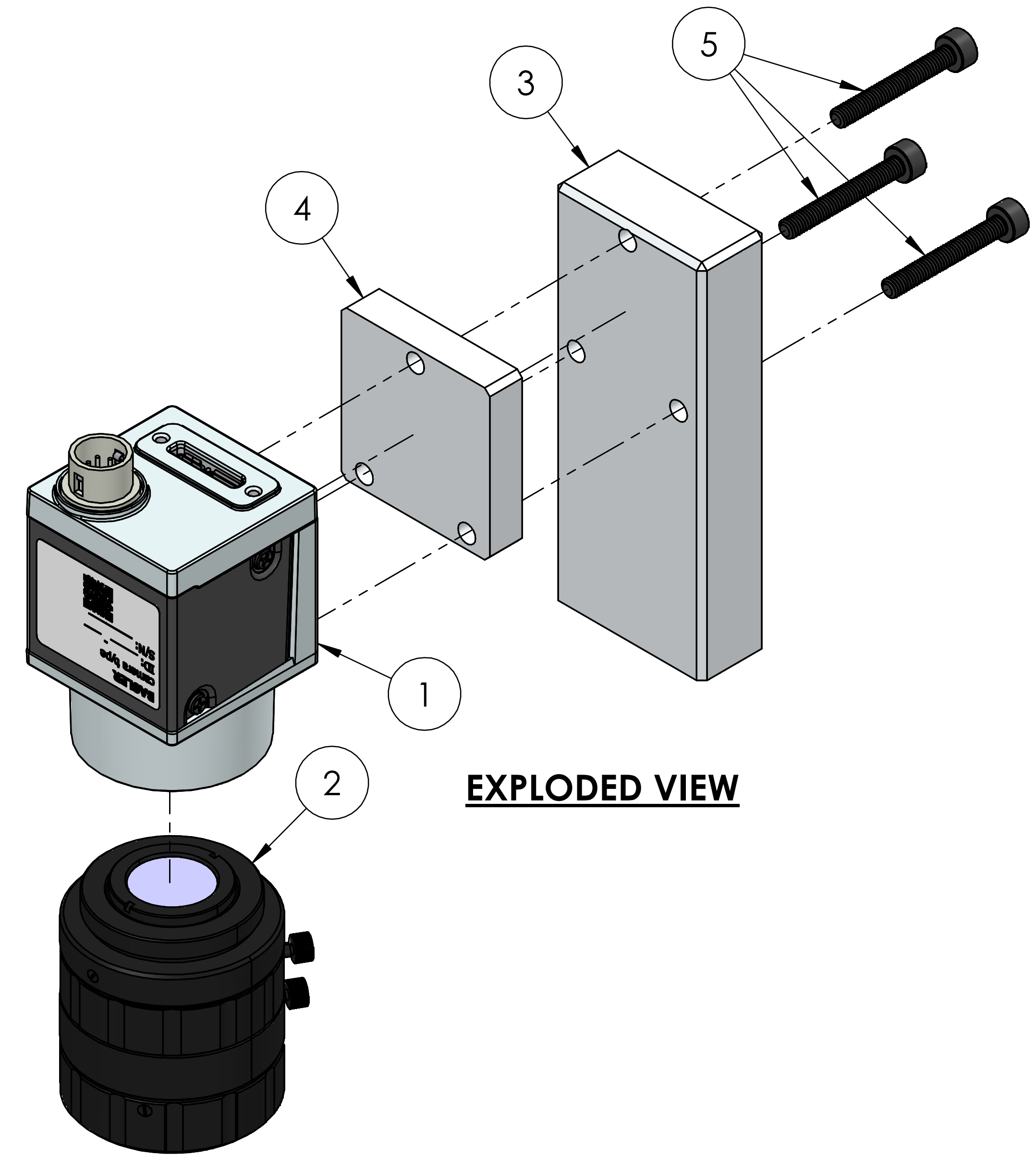
TITLE: **ZED MOUNTING ADAPTER**

PROJECT:	DWG NO.:			REV:
NEST	**10412**			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:1	1 OF 1	

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10421	ACA1300-200UC CAMERA	1
2	10422	EDMUND OPTICS 59-871 25MM LENS	1
3	10423	ACA1300 MOUNTING ADAPTER	1
4	10424	ACA1300 MOUNTING ADAPTER STANDOFF	1
5	10936	M3x0.5 - 6H 22MM SOCKET HEAD SCREW	3



ISOMETRIC VIEW



EXPLODED VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

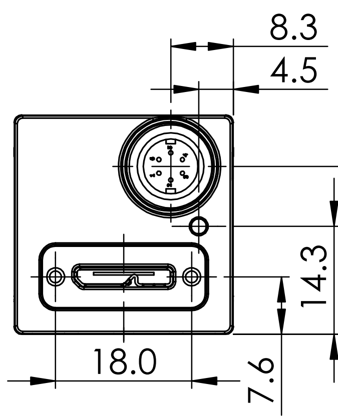
MATERIAL:

LASR

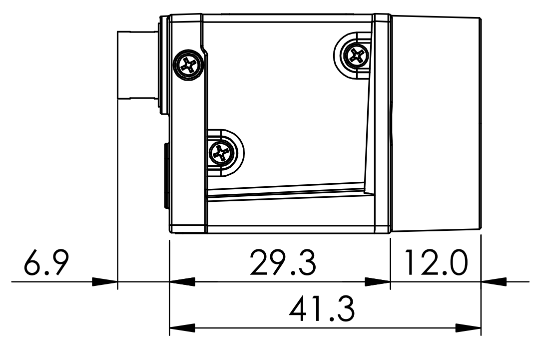
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **ACA1300 CAMERA MOUNTING ASSEMBLY**

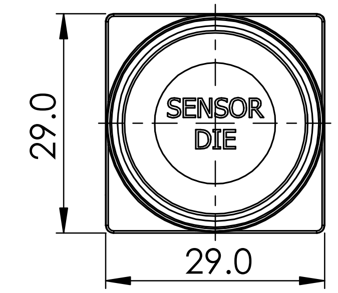
PROJECT:	DWG NO.:		REV:
NEST	**10420**		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:1	SHEET: 1 OF 1



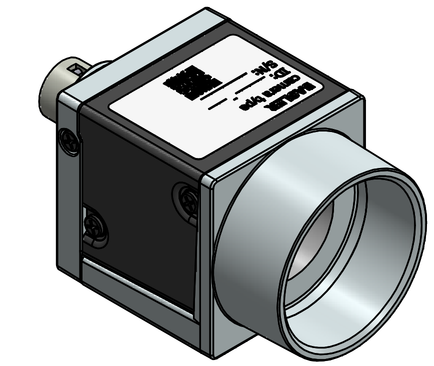
BACK VIEW

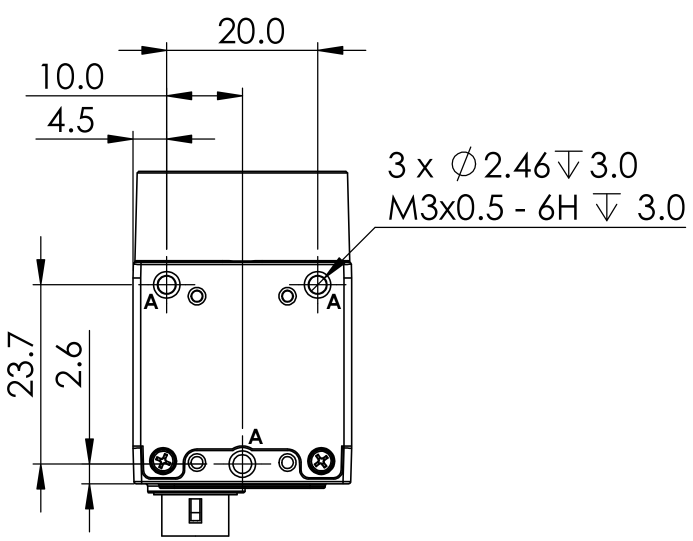


LEFT VIEW



FRONT VIEW





BOTTOM VIEW

SHEET NOTES:

1. THE CAD MODEL FOR THIS PART WAS PROVIDED BY THE MANUFACTURER AND MAJOR DIMENSIONS HAVE BEEN ADDED TO THIS DRAWING FOR REFERENCE. IF A MORE DETAILED DRAWING IS REQUIRED, PLEASE CONTACT THE MANUFACTURER.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10420	ACA1300 CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

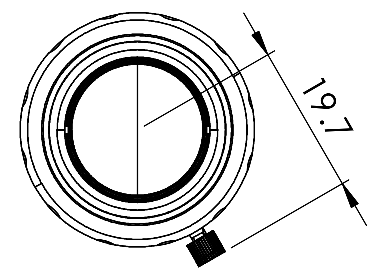
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

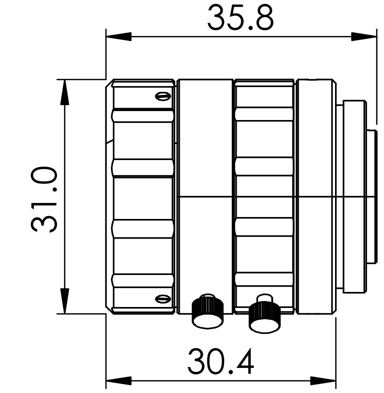
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **ACA1300-200UC CAMERA**

PROJECT:	DWG NO.:		REV:
NEST	**10421**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1



FRONT VIEW



SIDE VIEW

SHEET NOTES:

1. THE CAD MODEL FOR THIS PART WAS PROVIDED BY THE MANUFACTURER AND MAJOR DIMENSIONS HAVE BEEN ADDED TO THIS DRAWING FOR REFERENCE. IF A MORE DETAILED DRAWING IS REQUIRED, PLEASE CONTACT THE MANUFACTURER.
2. THE 19.7MM RADIAL DIMENSON OF THE EXTENT OF THE SET SCREW SHOW ON THE FRONT VIEW IS APPROXIMATE; LENGTH WILL VARY WITH SCREW TIGHTNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10420	ACA1300 CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

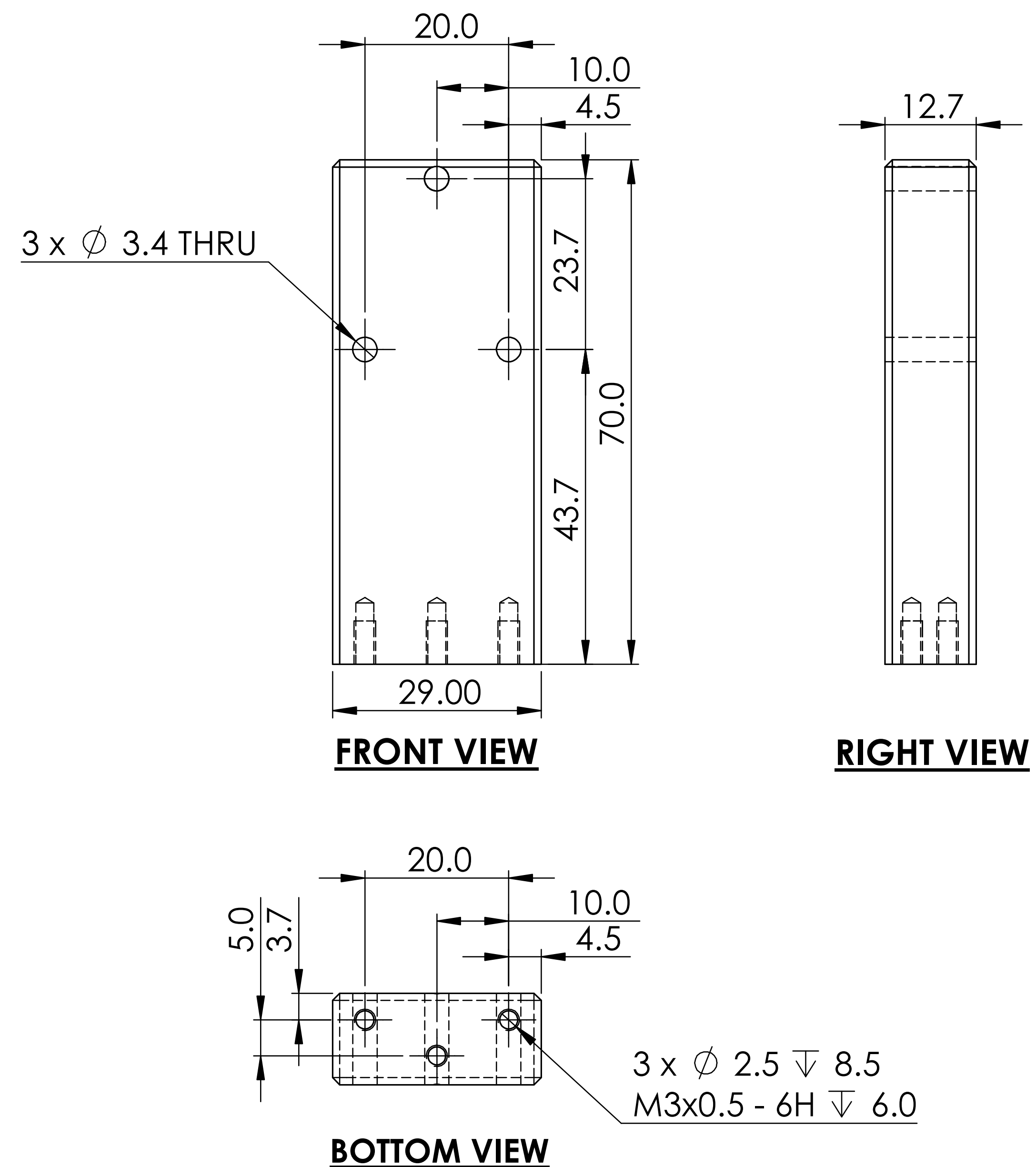
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

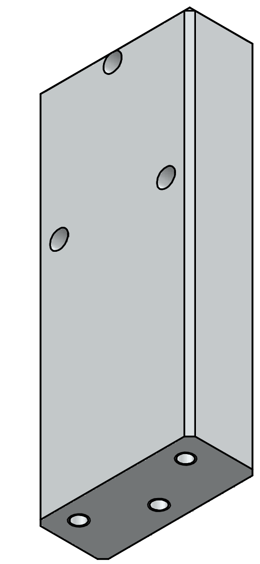
MATERIAL:

LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **EDMUND OPTICS 59-871 25MM LENS**

PROJECT:	DWG NO.:		REV:
NEST	10422		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1





SHEET NOTES:

1. 12.7MM DEPTH DIMENSION ON RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/2 INCH ALUMINUM BAR. PART MAY BE LEFT AT THE STOCK BAR THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10420	ACA1300 CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

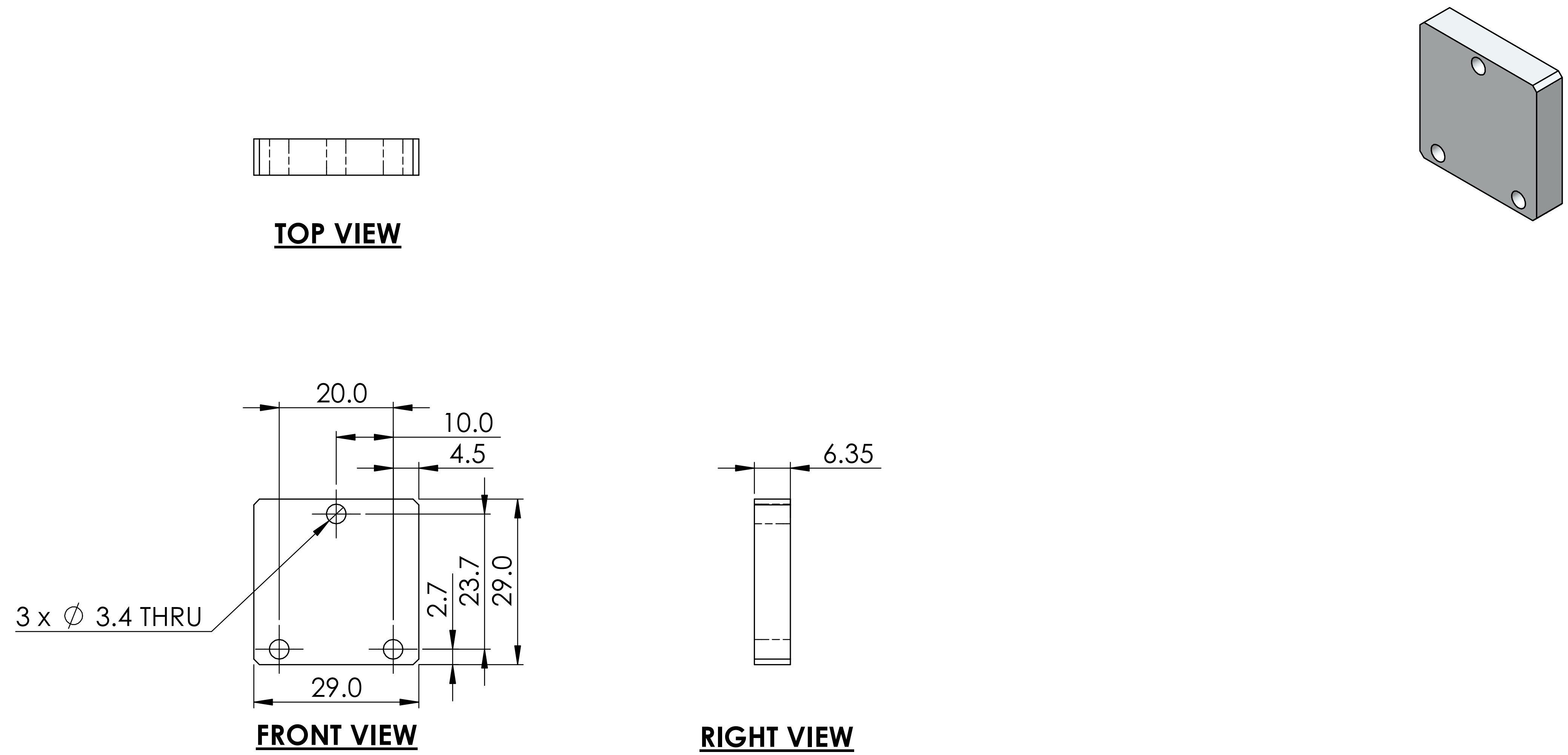
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **ACA1300 MOUNTING ADAPTER**

PROJECT:	DWG NO.:		REV:
NEST	10423		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1



SHEET NOTES:

1. 6.35MM DEPTH THICKNESS ON RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/4 INCH ALUMINUM BAR. PART MAY BE LEFT AT THE STOCK BAR THICKNESS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10420	ACA1300 CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: 6061-T6 ALUMINUM

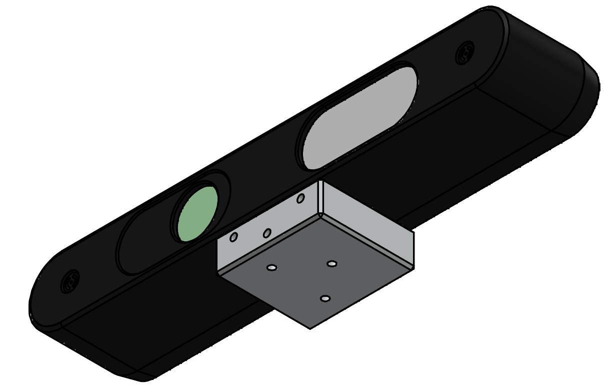
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

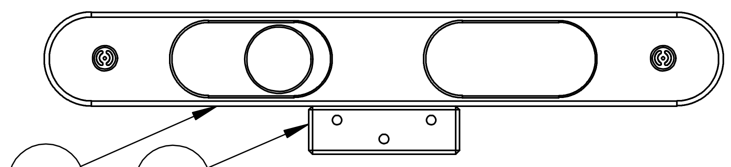
TITLE: **ACA1300 MOUNTING ADAPTER STANDOFF**

PROJECT:	DWG NO.:	REV:
NEST	10424	0

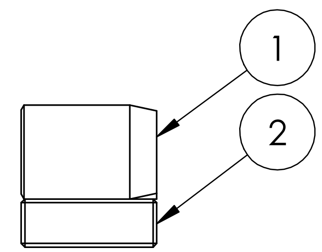
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10431	XTION CAMERA	1
2	10432	XTION MOUNTING ADAPTER	1

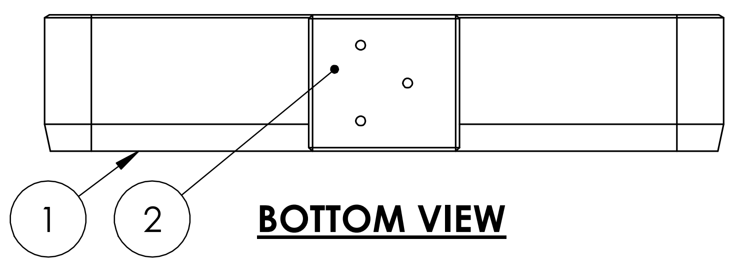




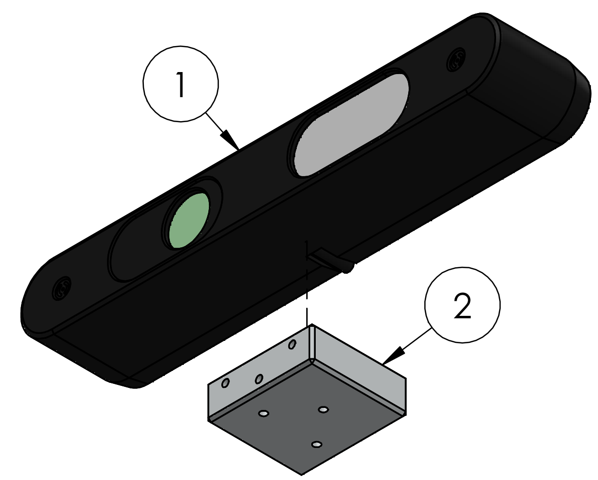
FRONT VIEW



RIGHT VIEW



BOTTOM VIEW



EXPLODED VIEW

SHEET NOTES:

1. XTION MOUNTING ADAPTER IS PERMANENTLY ADHERED TO THE XTION CAMERA USING EPOXY RESIN.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

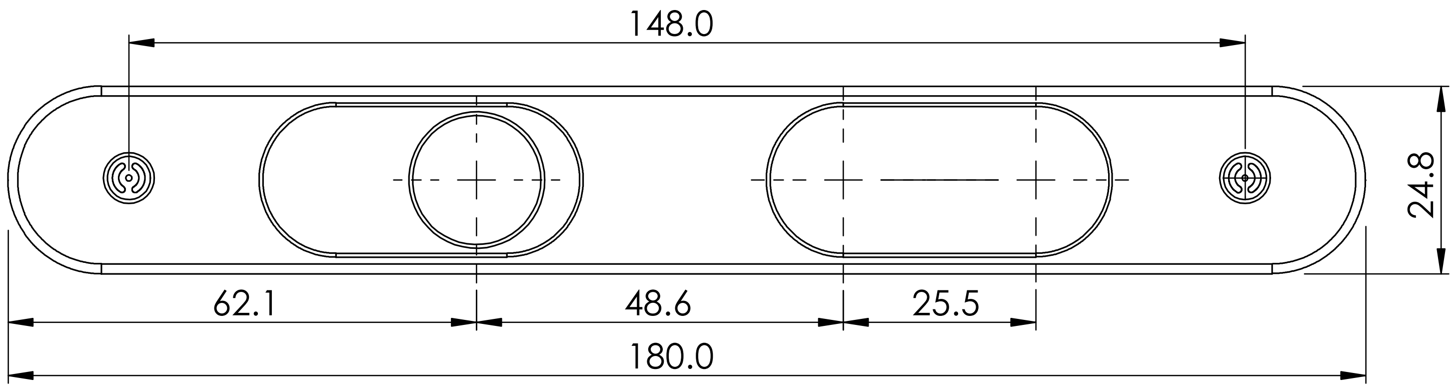
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

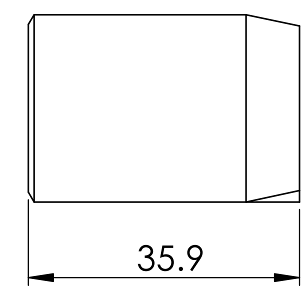
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

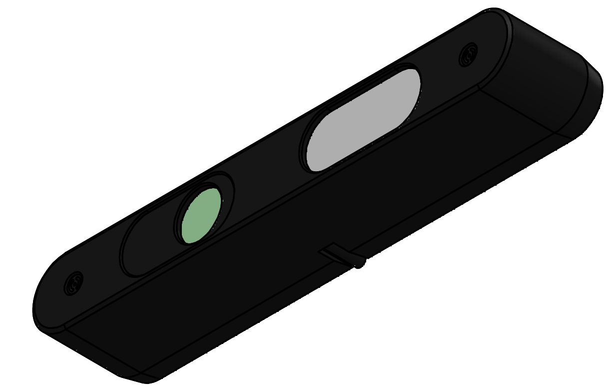
TITLE: XTION CAMERA MOUNTING ASSEMBLY			
PROJECT: NEST	DWG NO.: 10430		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 1 OF 1



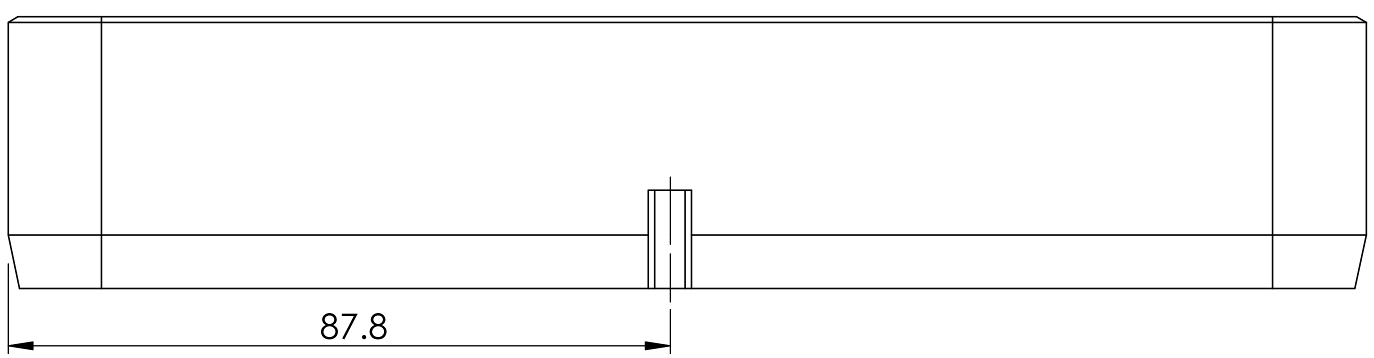
FRONT VIEW



RIGHT VIEW



SCALE 1 : 2



BOTTOM VIEW

SHEET NOTES:

1. AN ACCURATE CAD MODEL OF THE XTION WAS NOT AVAILABLE FROM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS RECREATED USING CALIPER MEASUREMENTS OF A UNIT PURCHASED BY THE LASR LAB. THEREFORE, DIMENSIONS ON THIS DRAWING SHALL BE CONSIDERED REASONABLY ACCURATE, BUT NOT PERFECT. FOR A MORE ACCURATE DRAWING, PLEASE CONTACT THE MANUFACTURER.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10430	XTION CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	AS MEASURED	A. SIMON

COMMENTS:

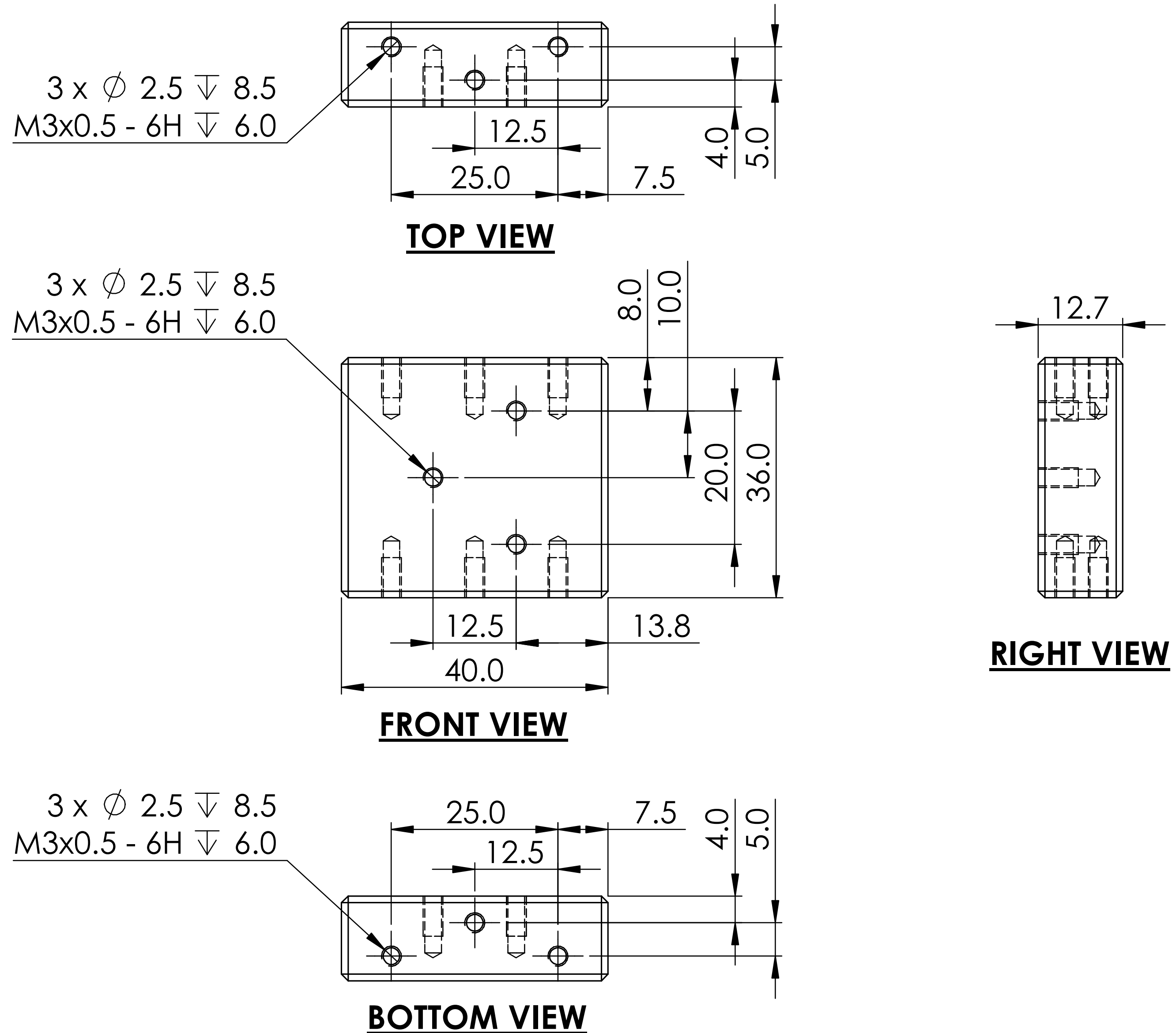
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

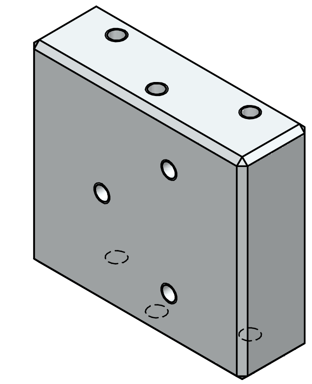
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
XTION CAMERA

PROJECT:	DWG NO.:		REV:
NEST	**10431**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1





SHEET NOTES:

1. 12.7MM DEPTH DIMENSION ON RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/2 INCH ALUMINUM BAR. PART MAY BE LEFT AT THE STOCK BAR THICKNESS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10430	XTION CAMERA MOUNTING ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES
-- CHAMFER ALL EDGES
-- CHAMFER ALL HOLES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

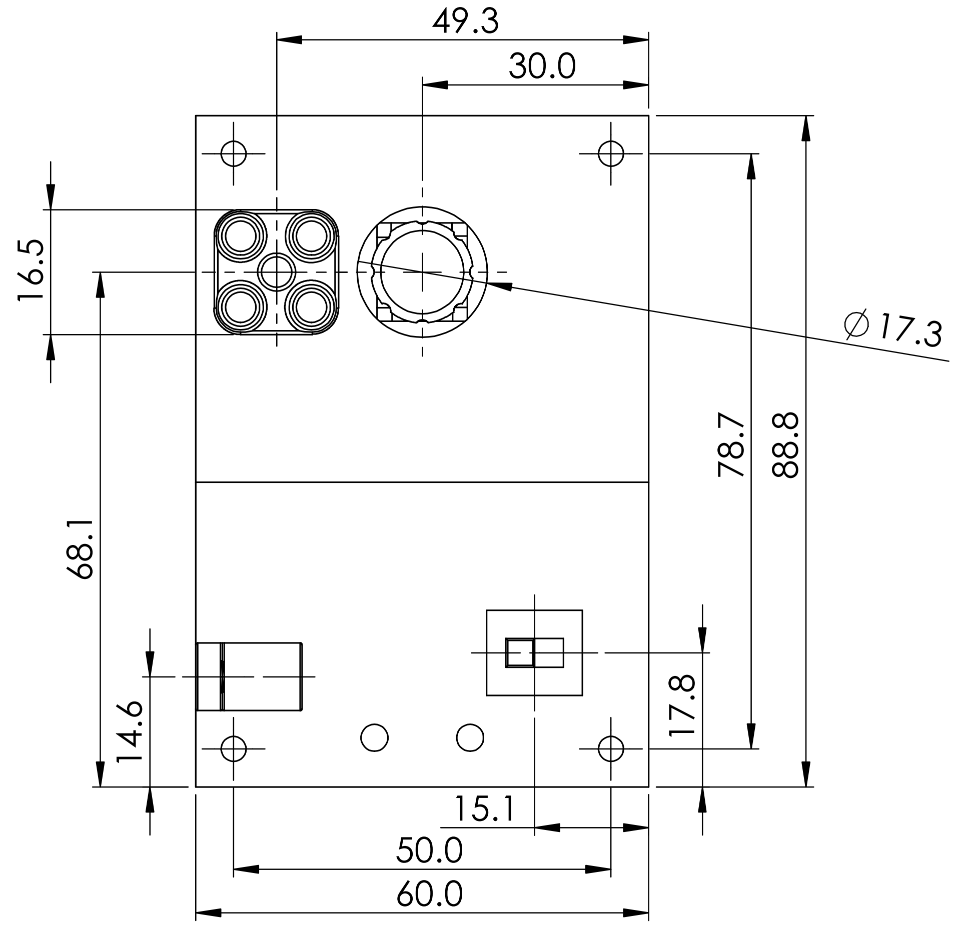
MATERIAL: 6061-T6 ALUMINUM

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

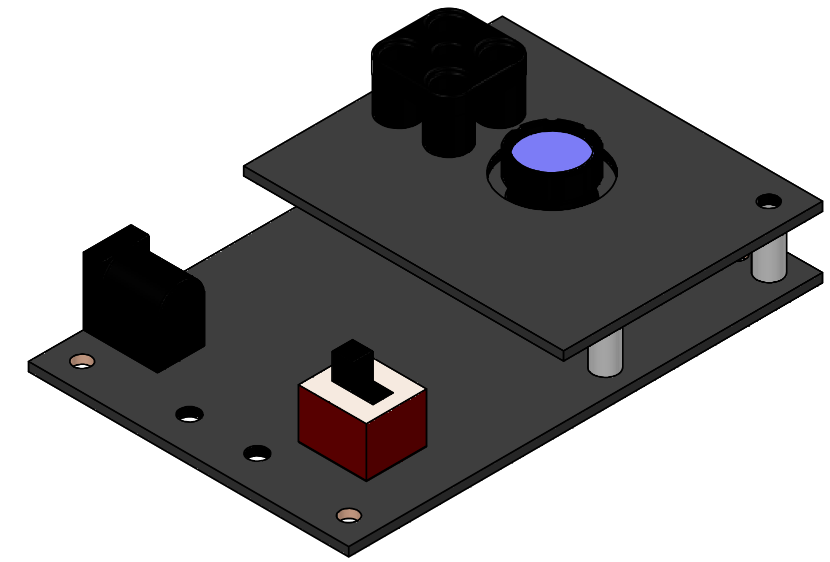
TITLE: **XTION MOUNTING ADAPTER**

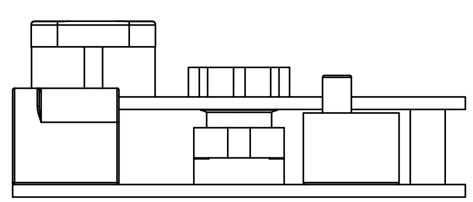
PROJECT:	DWG NO.:	REV:
NEST	10432	0

DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1

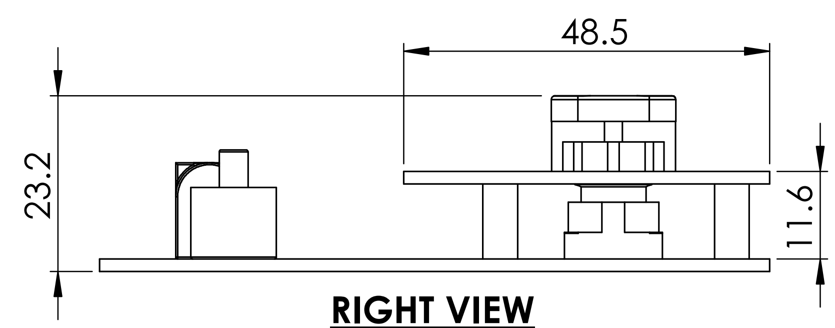


TOP VIEW





FRONT VIEW



RIGHT VIEW

SHEET NOTES:

1. A CAD MODEL OF THIS PART WAS NOT AVAILABLE FROM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS CREATED USING CALIPER MEASUREMENTS OF A UNIT PURCHASED BY THE LASR LAB. MINOR FEATURES HAVE BEEN OMITTED. ONLY SIGNIFICANT DIMENSIONS HAVE BEEN ADDED TO THIS DRAWING. THIS DRAWING SHALL BE CONSIDERED REASONABLY ACCURATE, BUT NOT PERFECT.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

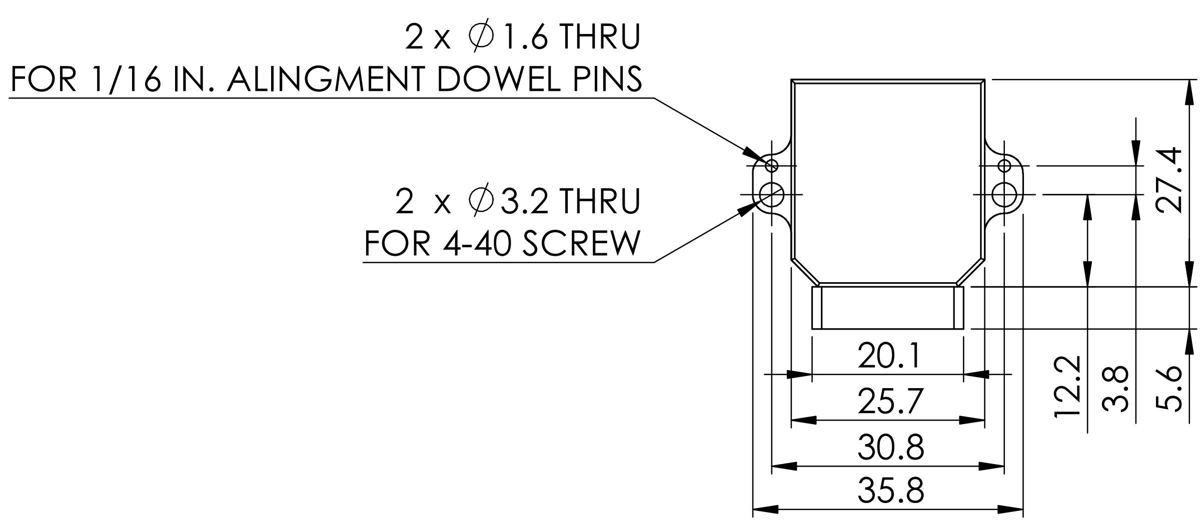
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

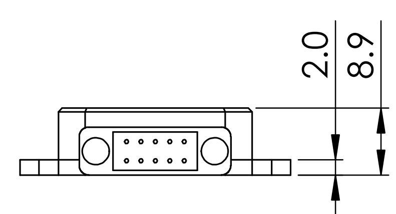
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **OPT8241-CDK-EVM LIDAR MODULE**

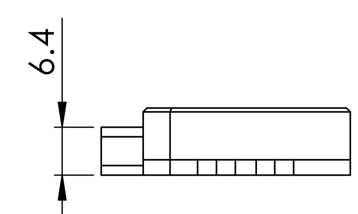
PROJECT:	DWG NO.:			REV:
NEST	**10441**			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:1	1 OF 1	



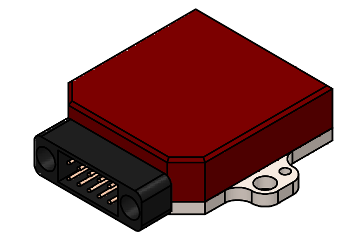
TOP VIEW



FRONT VIEW



RIGHT VIEW



SHEET NOTES:

1. A CAD MODEL FOR THIS PART WAS NOT AVAILABLE FROM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS RECONSTRUCTED FROM DETAILED DRAWINGS PROVIDED BY THE MANUFACTURER. MINOR DETAILS SUCH AS THE MANUFACTURER LOGO WERE NOT INCLUDED IN THE RECONSTRUCTED CAD MODEL.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

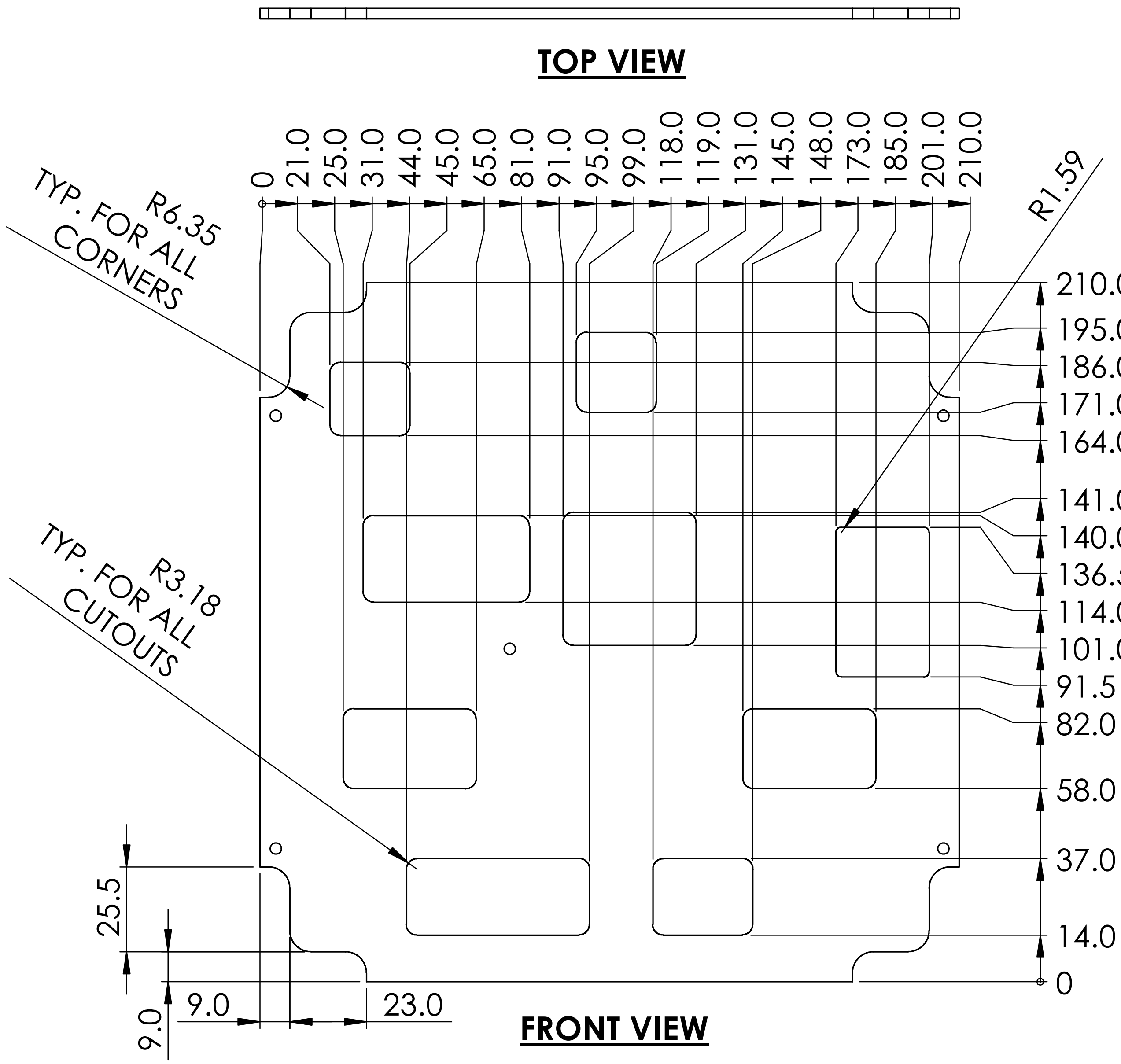
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

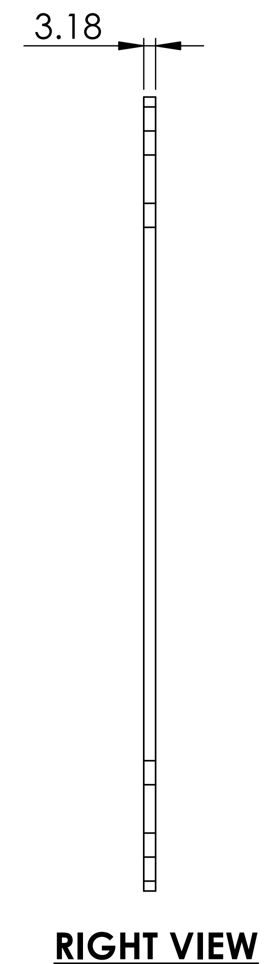
MATERIAL:

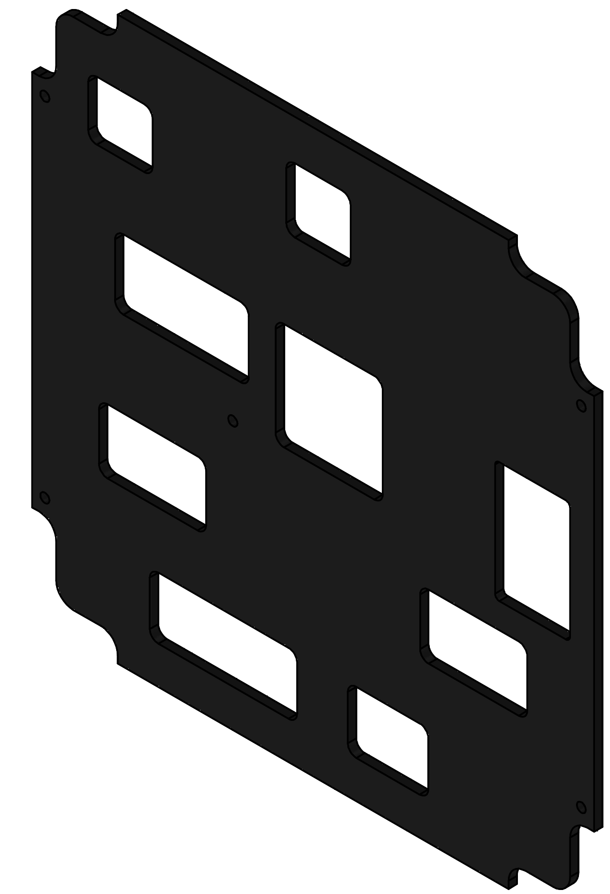
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
VN-100 RUGGED IMU

PROJECT:	DWG NO.:		REV:
NEST	**10451**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1







SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ACRYLIC SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

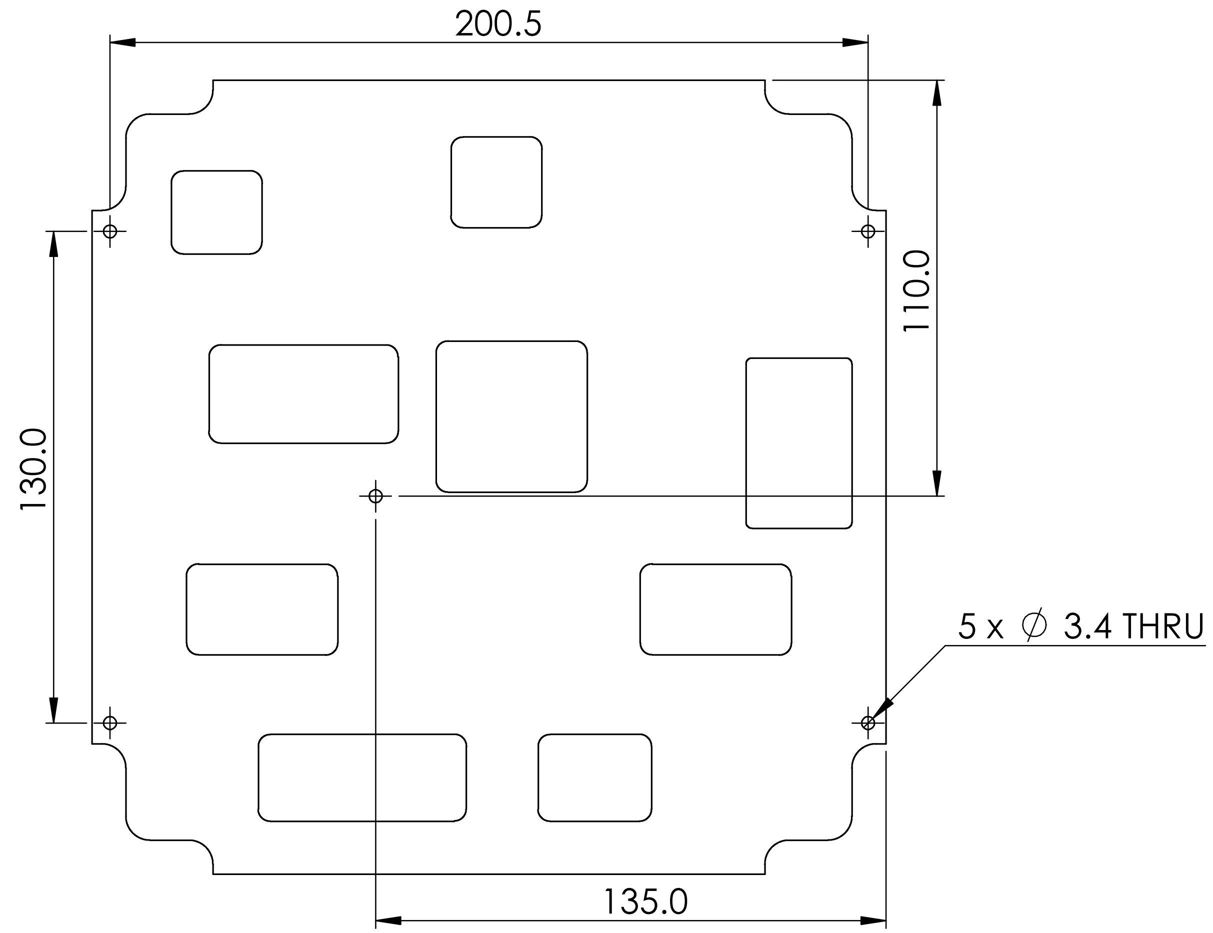
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: ACRYLIC

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SIDING FRONT**

PROJECT:	DWG NO.:			REV:
NEST	10511			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	1 OF 2	



FRONT VIEW - HOLE DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

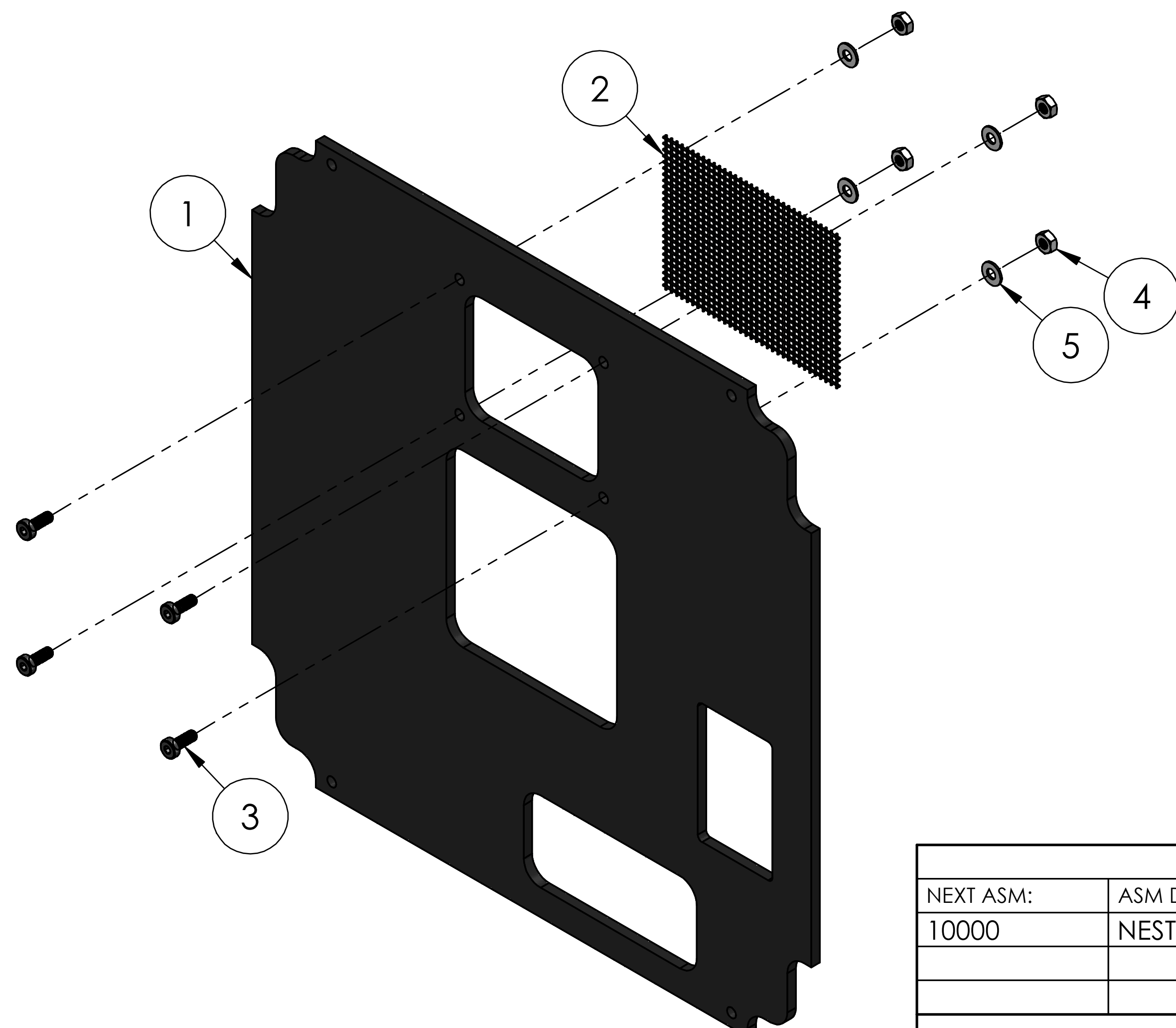
MATERIAL: ACRYLIC

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

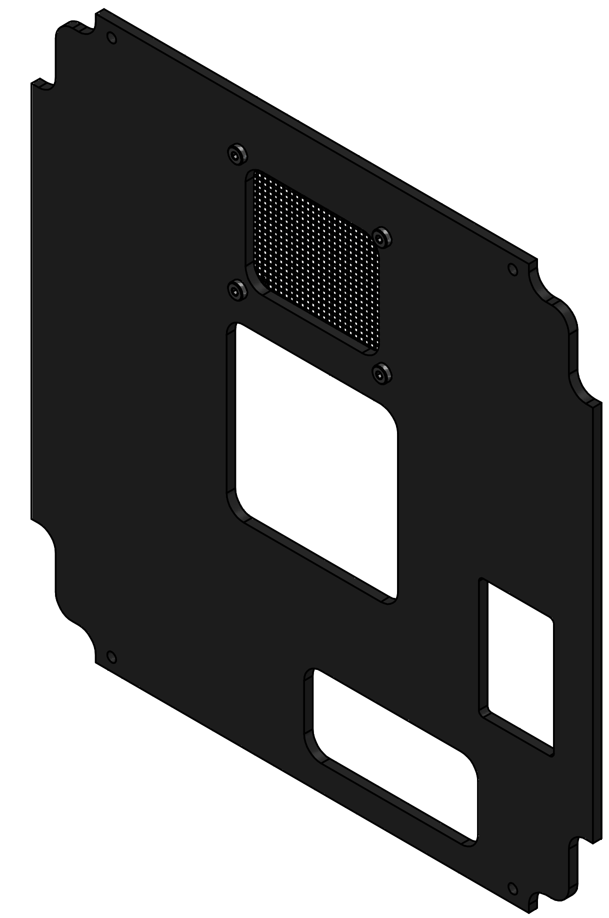
TITLE: **SIDING FRONT**

PROJECT:	DWG NO.:		REV:
NEST	**10511**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	2 OF 2

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10521	SIDING BACK	1
2	---	STAINLESS STEEL WIRE MESH, 0.5MM WIRE, 12 WIRE/INCH	1
3	10932	M3x0.5 - 6H 8MM LOW PROFILE SOCKET HEAD SCREW	4
4	10981	M3 HEX NUT	4
5	10971	M3 WASHER	4



EXPLODED VIEW



ISOMETRIC VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

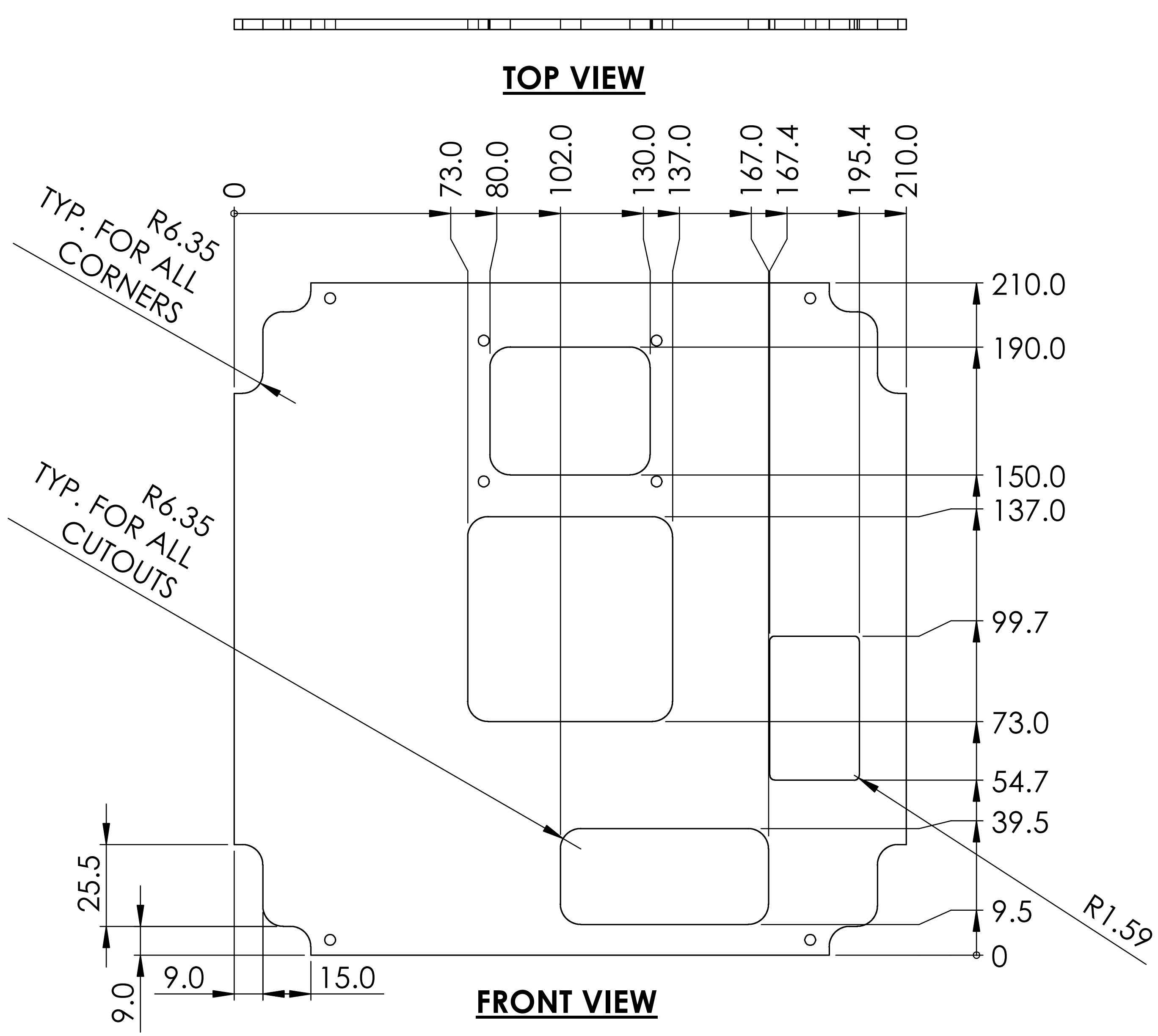
REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

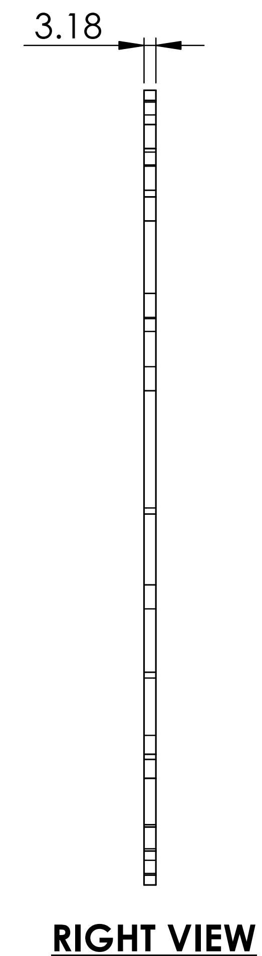
COMMENTS:

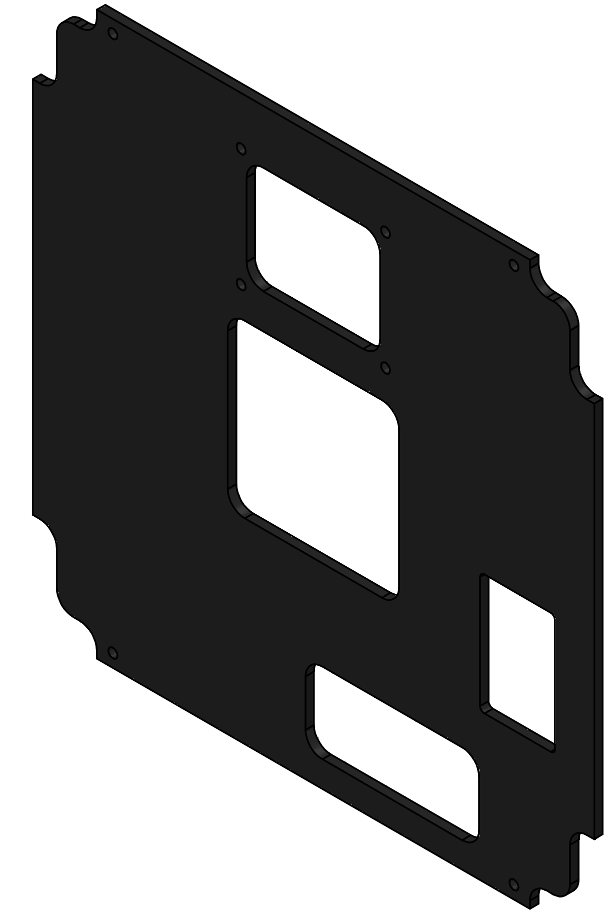
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:			
SIDING BACK ASSEMBLY			
PROJECT: NEST	DWG NO.: 10520		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:2	SHEET: 1 OF 1







SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ACRYLIC SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10520	SIDING BACK ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

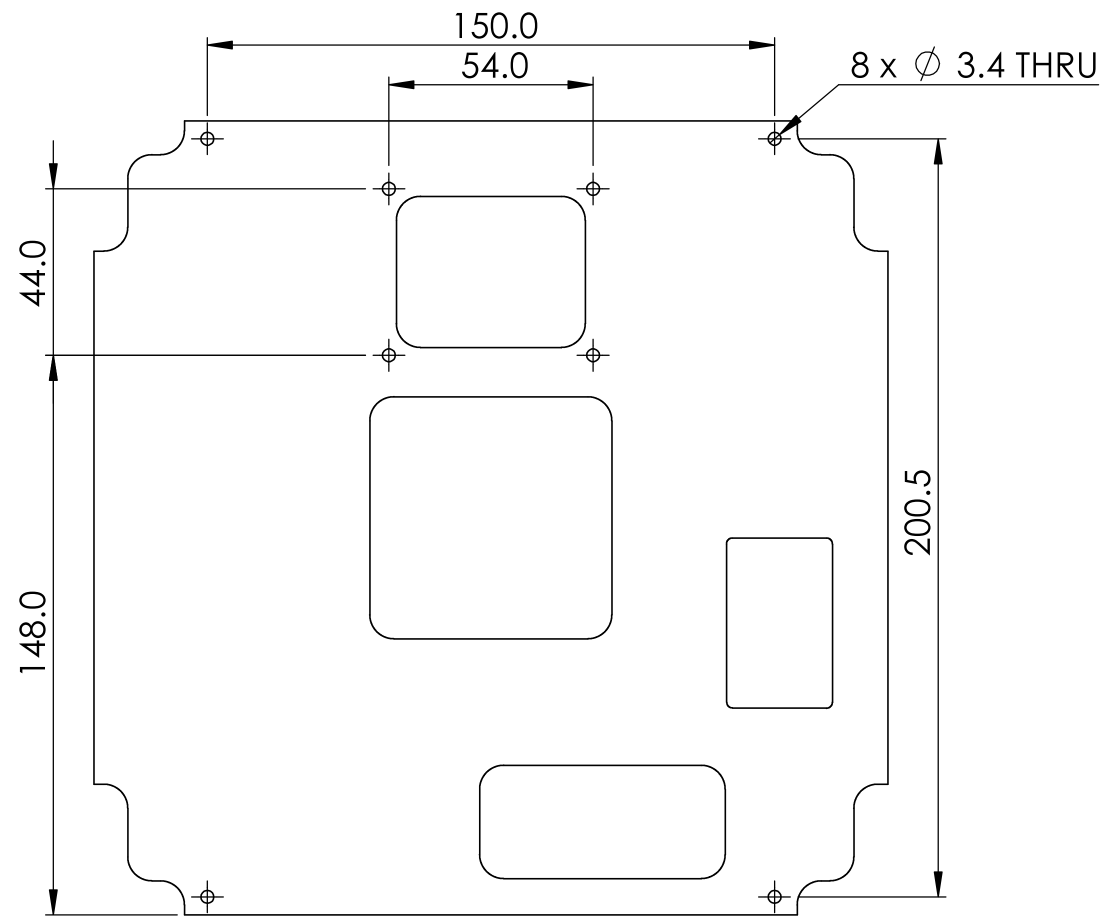
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL:
ACRYLIC

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
SIDING BACK

PROJECT:	DWG NO.:		REV:
NEST	10521		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 2



FRONT VIEW - HOLE DETAIL

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10520	SIDING BACK ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

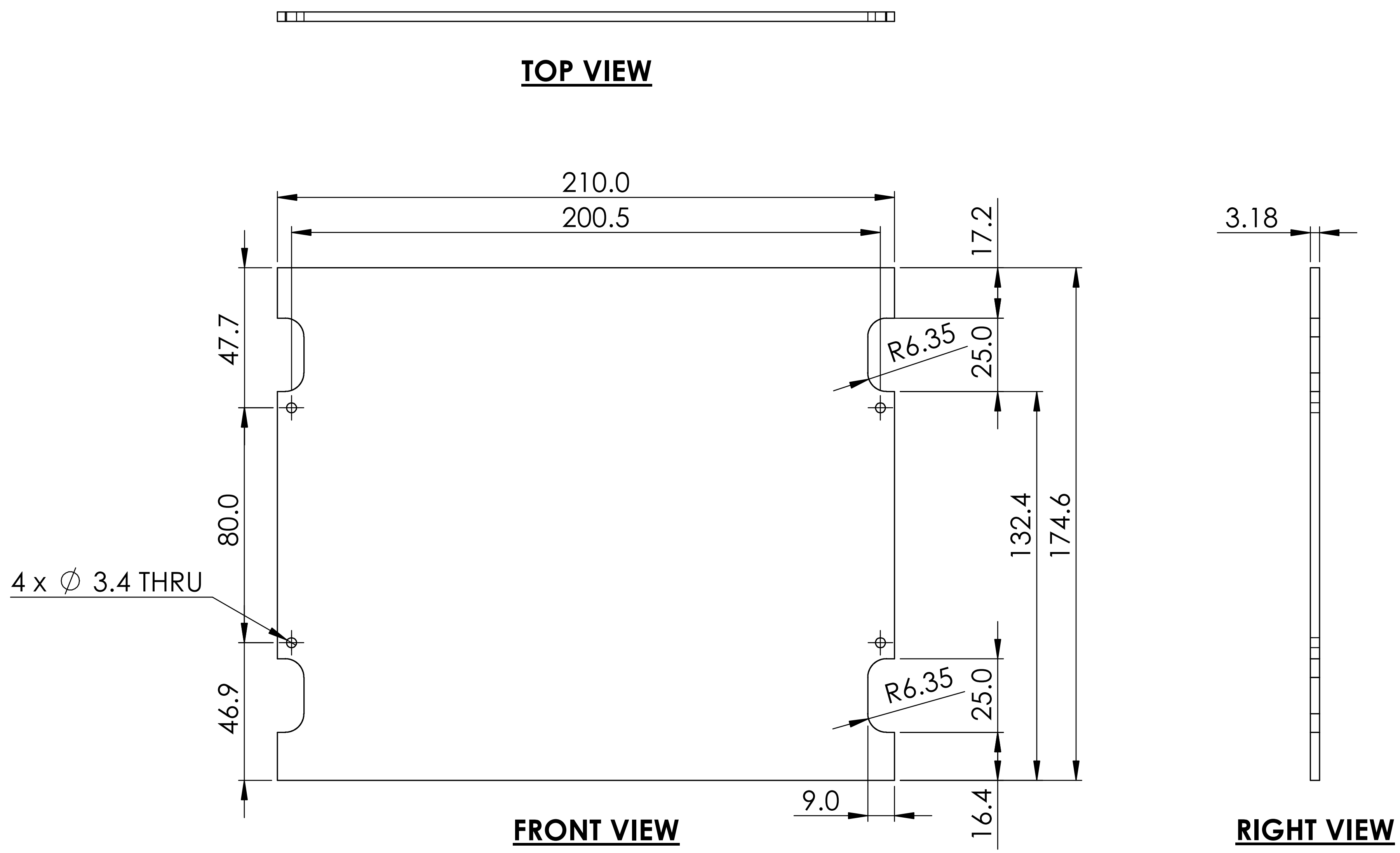
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

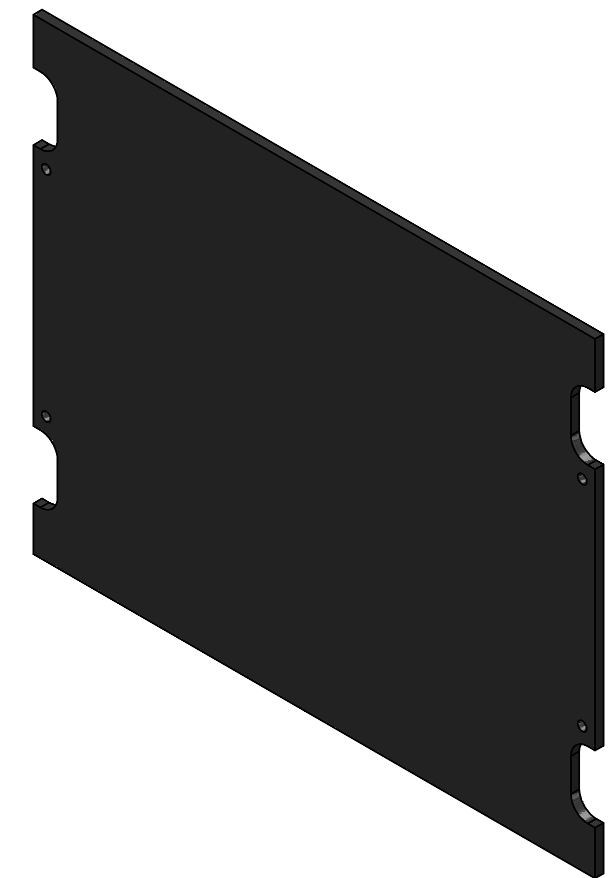
MATERIAL: ACRYLIC

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SIDING BACK**

PROJECT:	DWG NO.:			REV:
NEST	**10521**			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	2 OF 2	





SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ACRYLIC SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

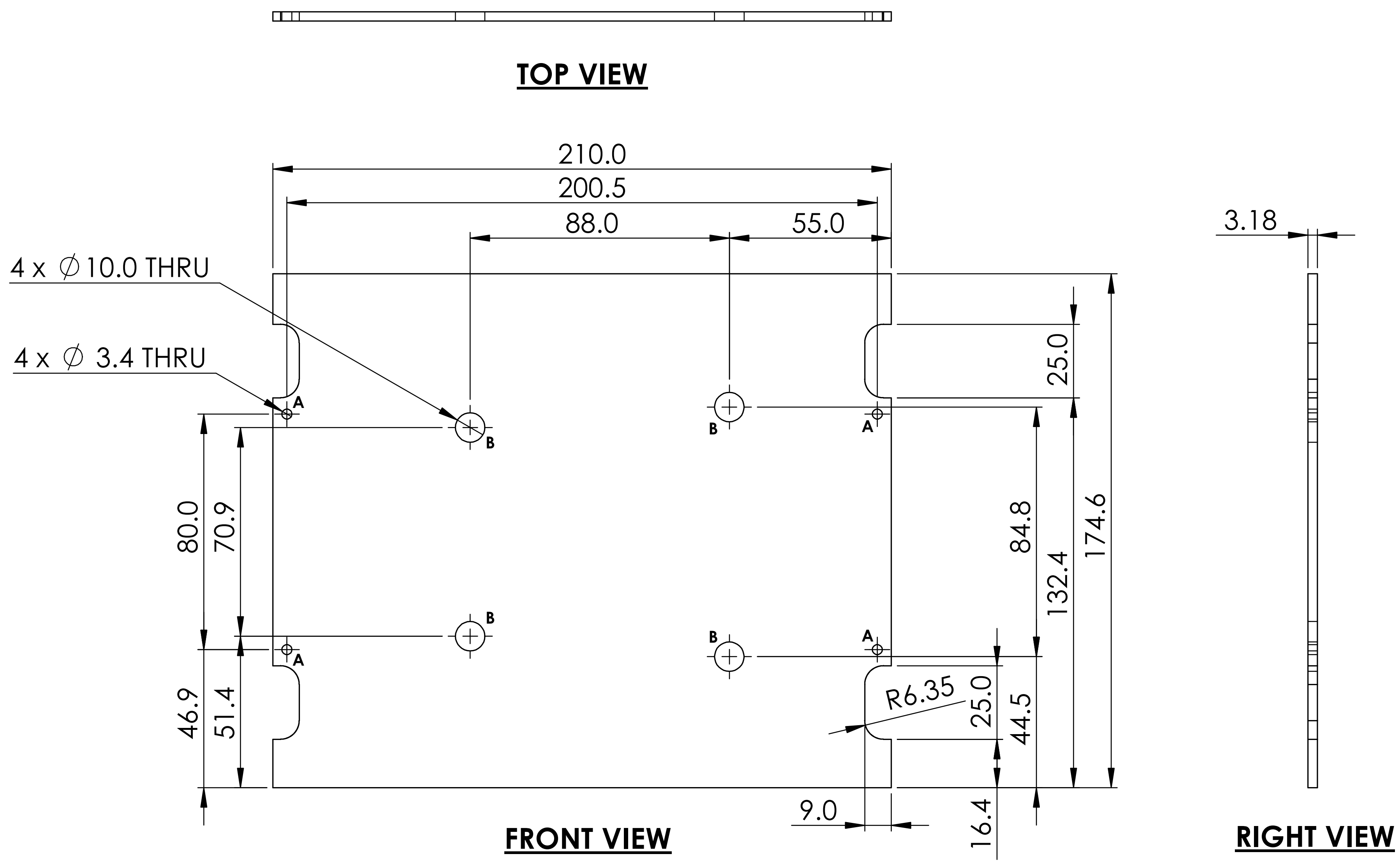
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

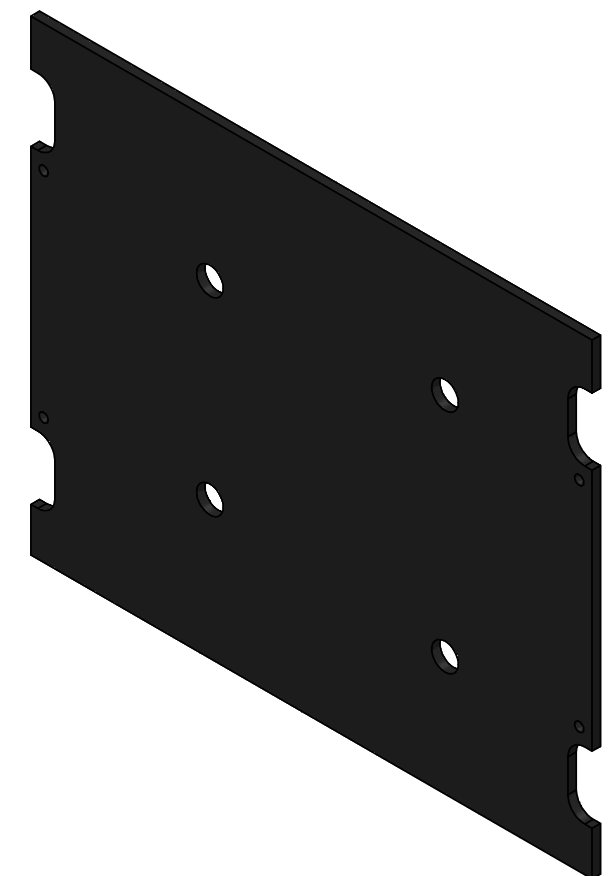
MATERIAL:
ACRYLIC

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
SIDING TOP

PROJECT:	DWG NO.:		REV:
NEST	**10531**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1





SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ACRYLIC SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

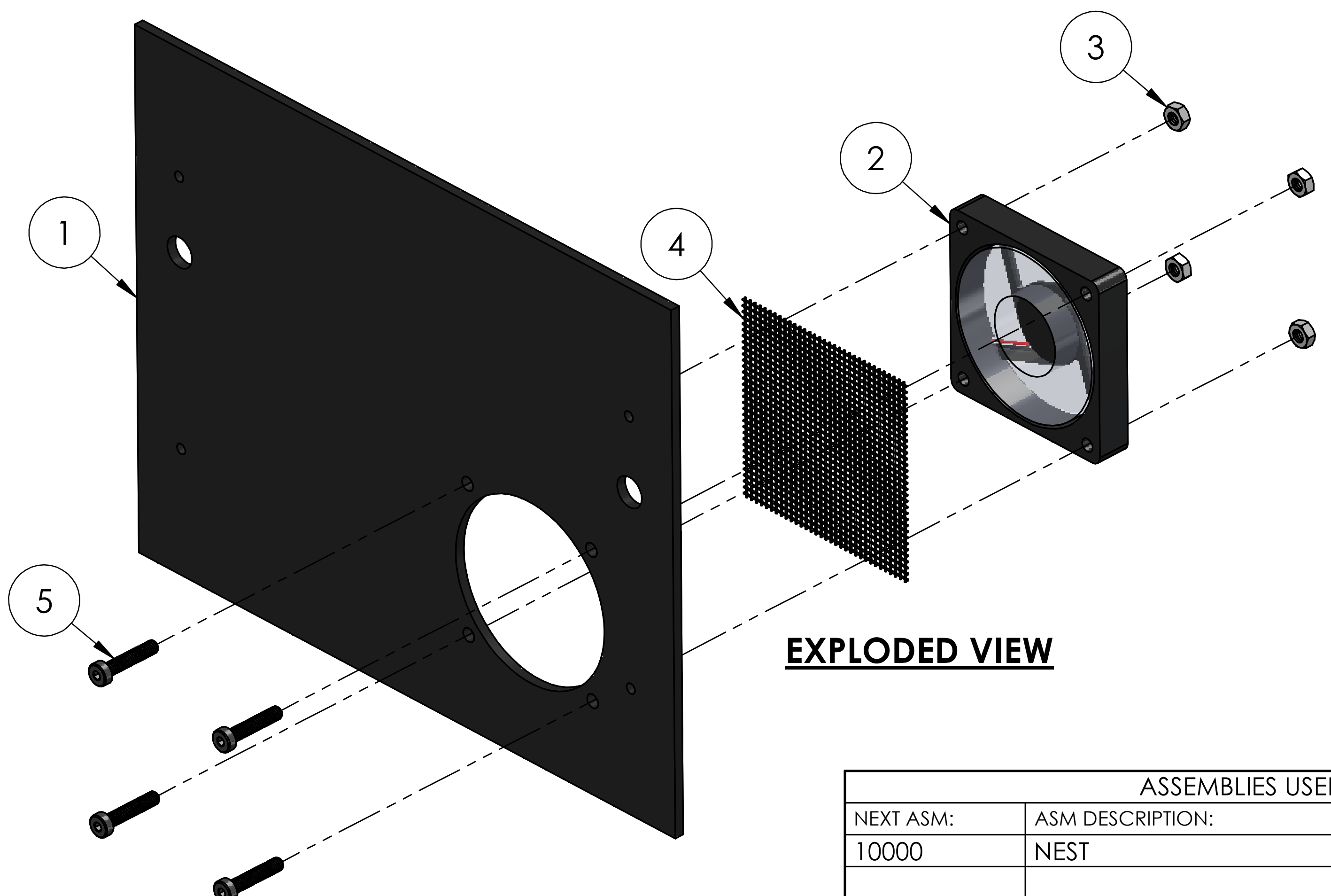
MATERIAL: ACRYLIC

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

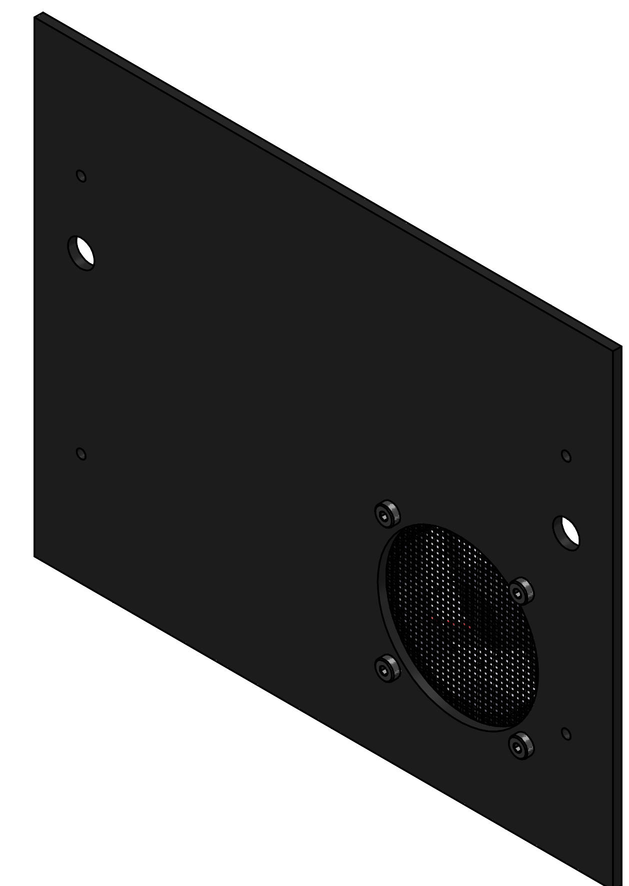
TITLE: **SIDING BOTTOM**

PROJECT:	DWG NO.:		REV:
NEST	10541		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1

ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	10551	SIDING LEFT	1
2	10721	60MM COOLING FAN	1
3	10982	M4 HEX NUT	4
4	---	STAINLESS STEEL WIRE MESH, 0.5MM WIRE, 12 WIRES/INCH	1
5	10945	M4x0.7 - 6H 20MM LOW PROFILE SOCKET HEAD SCREW	4



EXPLODED VIEW



ISOMETRIC VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

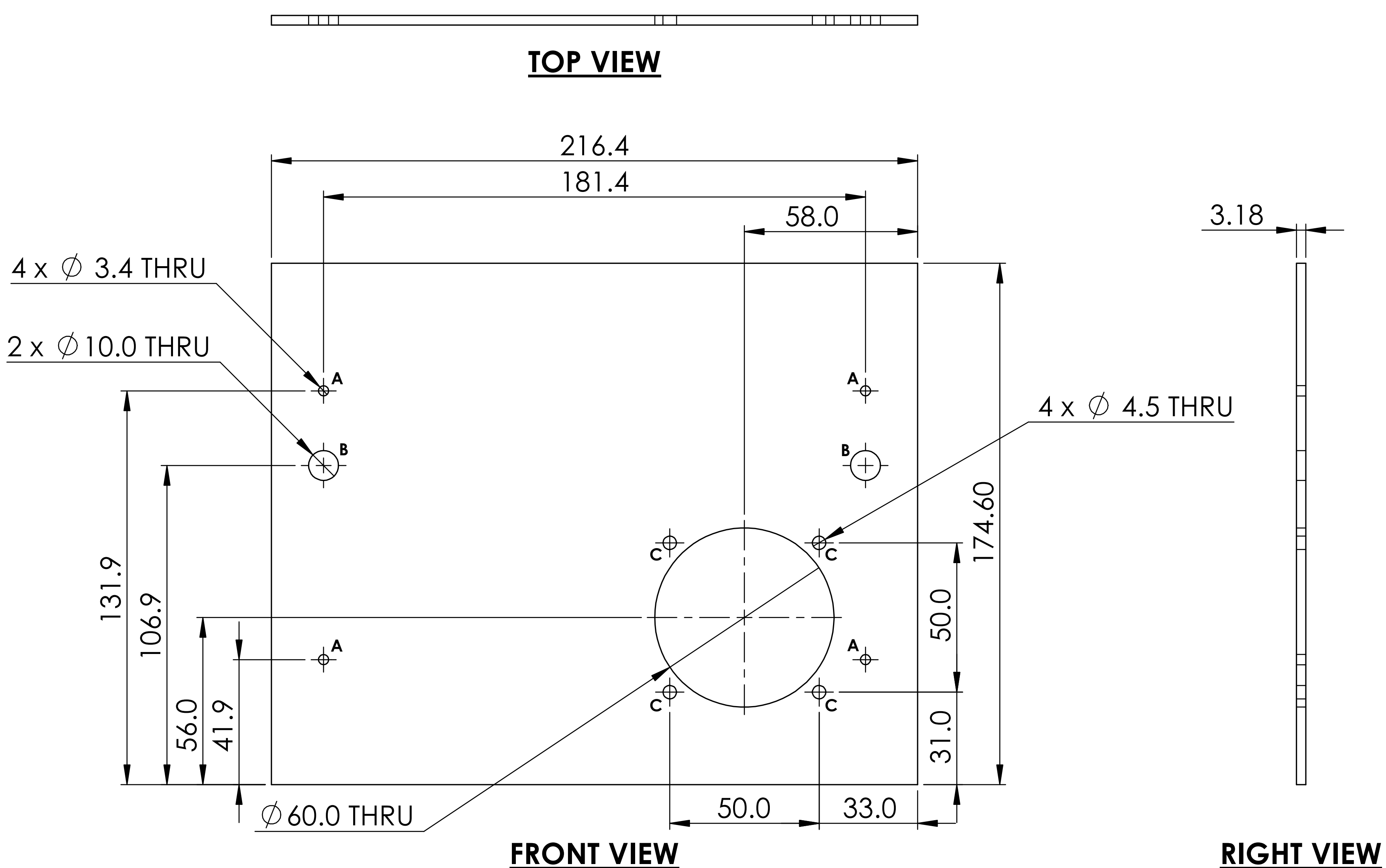
COMMENTS:

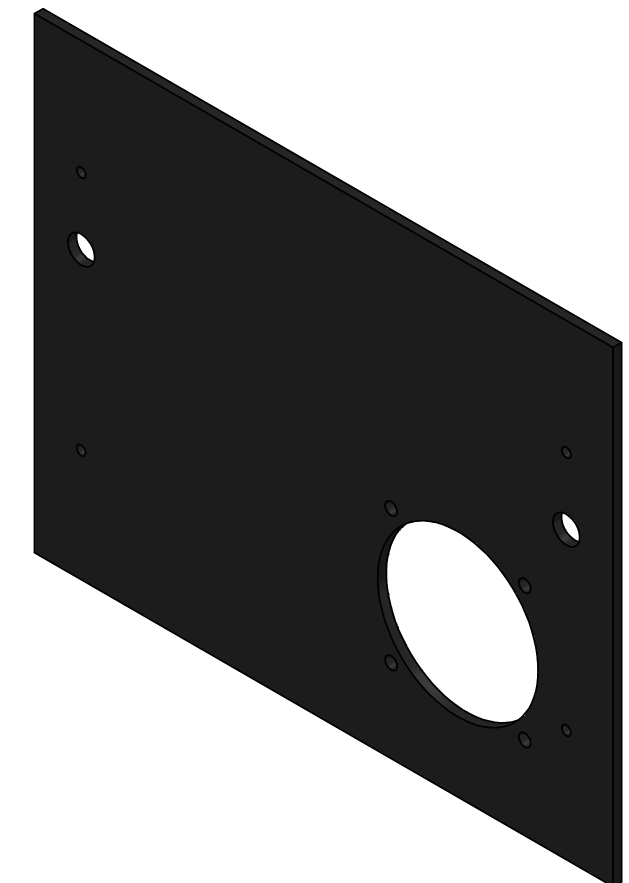
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SIDING LEFT ASSEMBLY**

PROJECT:	DWG NO.:		REV:
NEST	10550		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1





SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ACRYLIC SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10550	SIDING LEFT ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

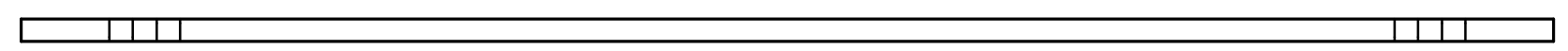
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: ACRYLIC

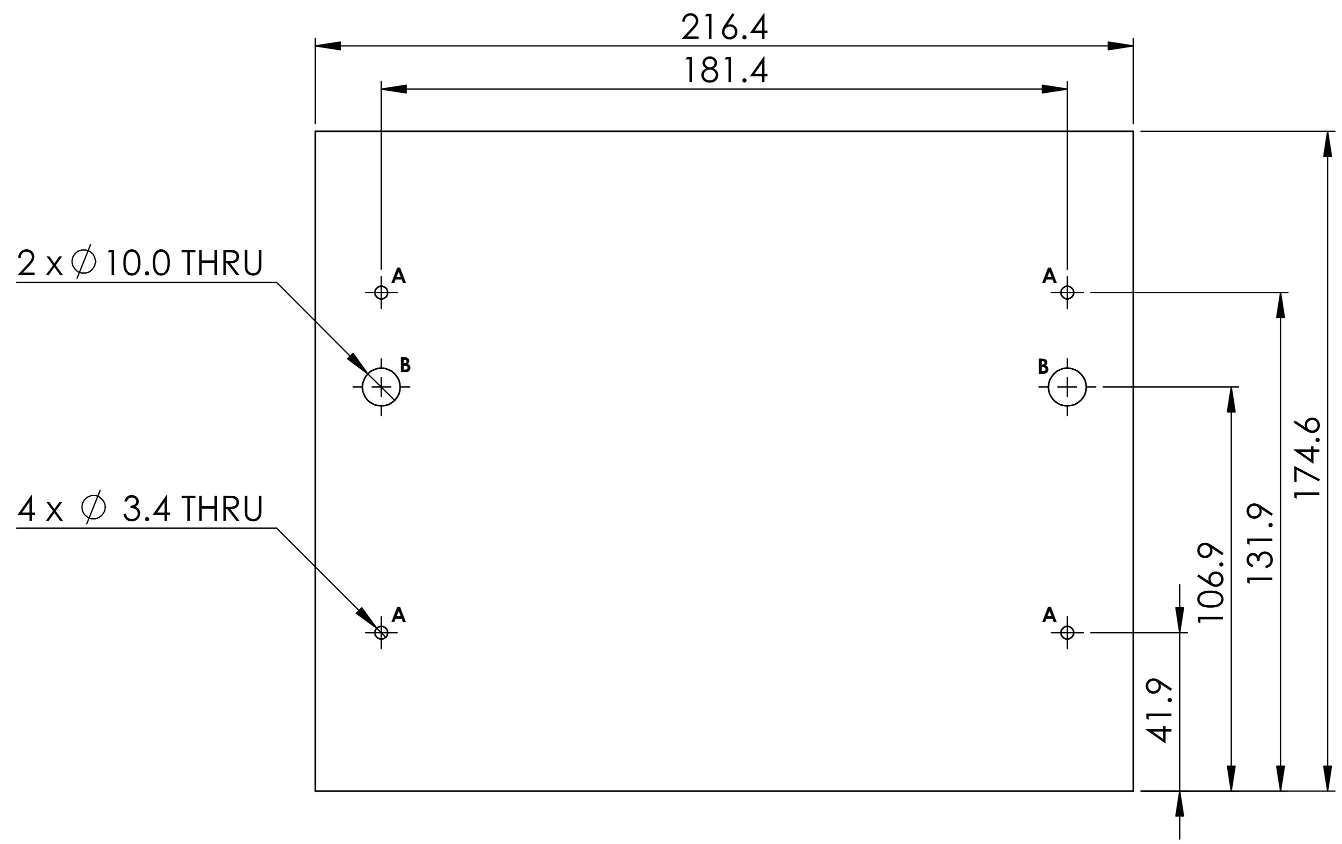
LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE: **SIDING LEFT**

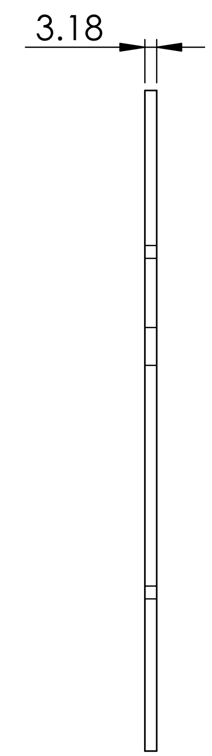
PROJECT:	DWG NO.:		REV:
NEST	10551		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:2	1 OF 1



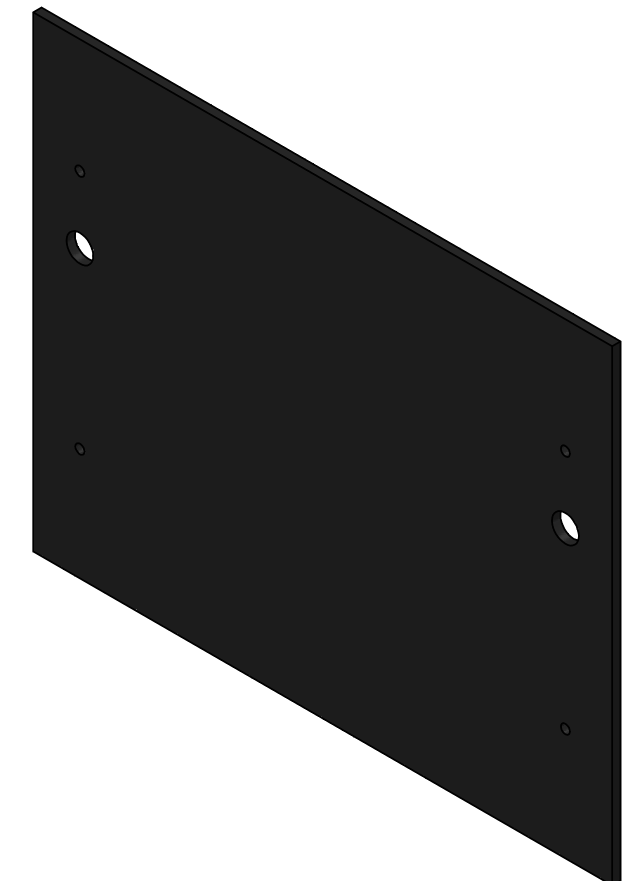
TOP VIEW



FRONT VIEW



RIGHT VIEW



SHEET NOTES:

1. THE 3.18MM DEPTH DIMENSION SHOWN ON THE RIGHT VIEW IS DRIVEN BY THE THICKNESS OF STOCK 1/8 INCH ACRYLIC SHEET. PART MAY BE LEFT AT THE STOCK SHEET THICKNESS.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10000	NEST	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:
-- DEBURR ALL EDGES

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM
-- LINEAR TOL.: ± 0.1 MM
-- ANGULAR TOL.: ± 0.5 DEG

MATERIAL: ACRYLIC

LASR
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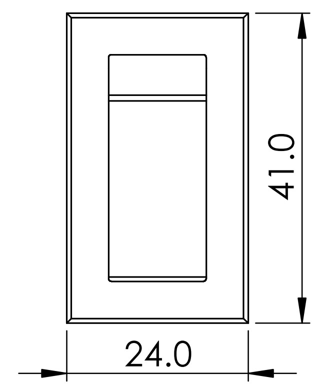
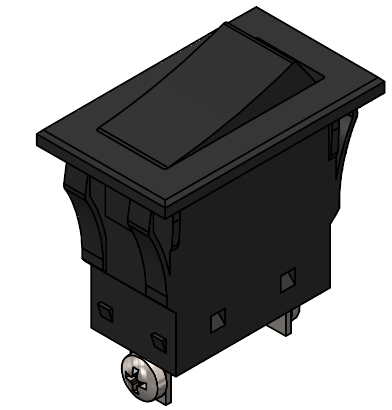
TITLE: **SIDING RIGHT**

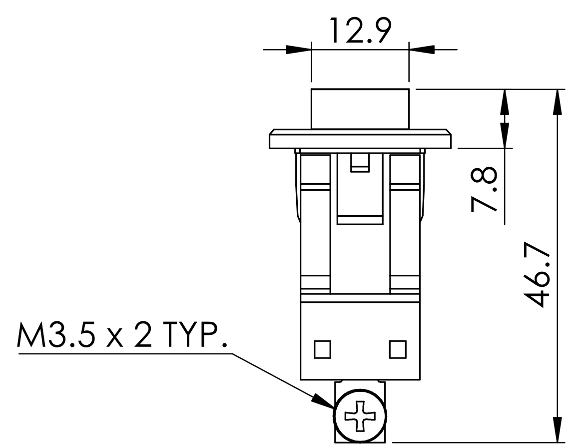
PROJECT:	DWG NO.:			REV:
NEST	10561			0
DATE:	SIZE:	SCALE:	SHEET:	
03/20/20	ANSI B	1:2	1 OF 1	

PANEL CUTOUT FOR SWITCH MOUNTING

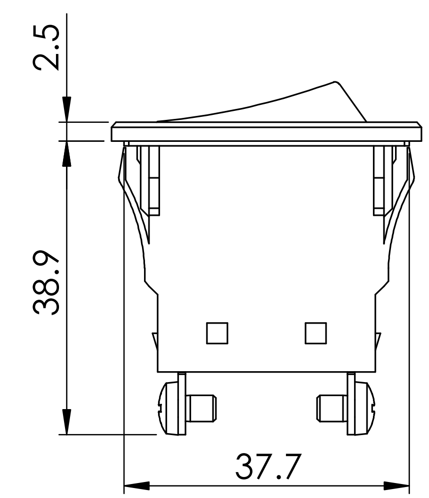


TOP VIEW





FRONT VIEW



RIGHT VIEW

ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	SENSOR ARRAY ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

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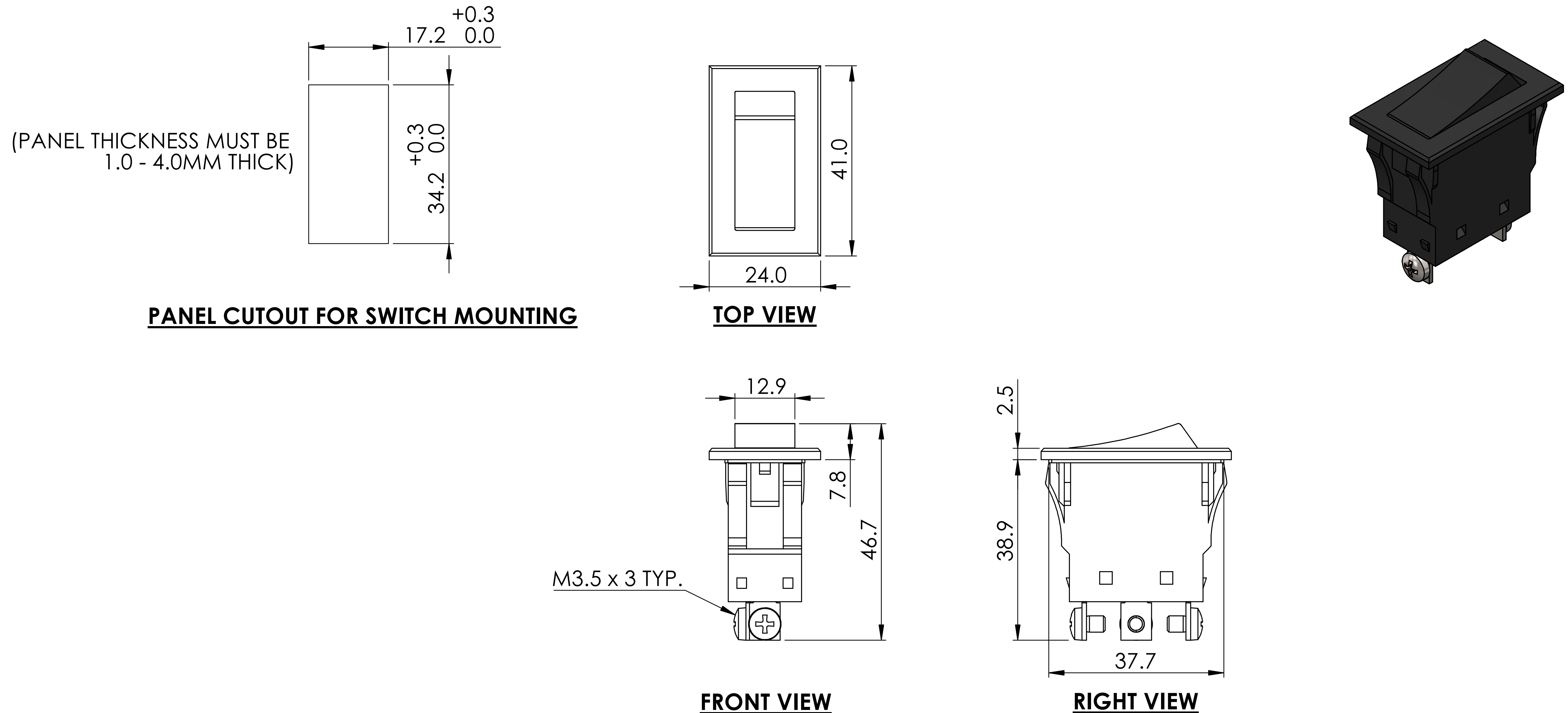
TITLE:			
SPST ROCKER SWITCH			
PROJECT: NEST	DWG NO.: 10711		REV: 0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:1	SHEET: 1 OF 1



ASSEMBLIES USED		
NEXT ASM:	ASM DESCRIPTION:	QTY:
10400	NEST ASSEMBLY	1

REVISION HISTORY			
REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	FROM MANUFACTURER	A. SIMON

COMMENTS:

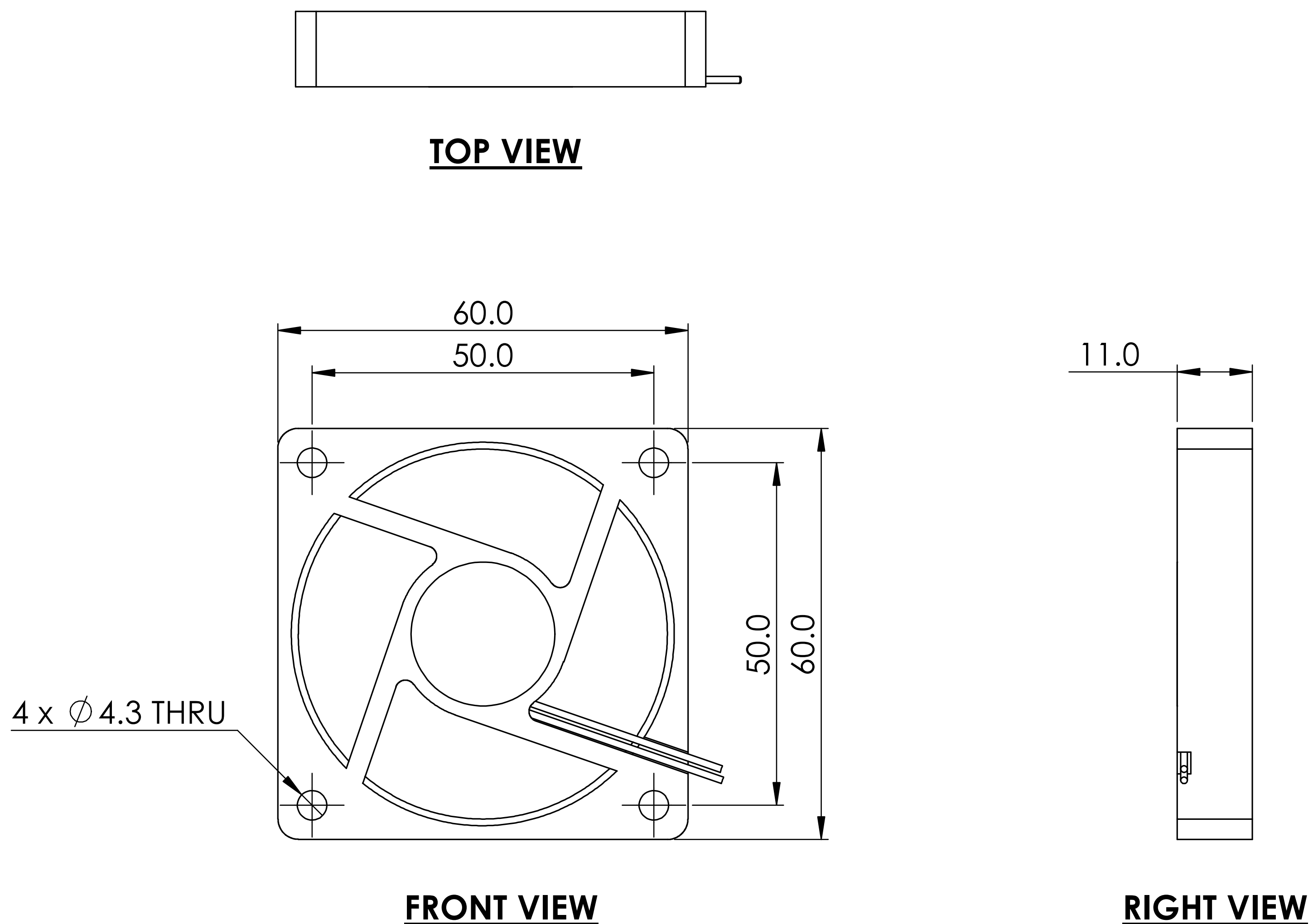
UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

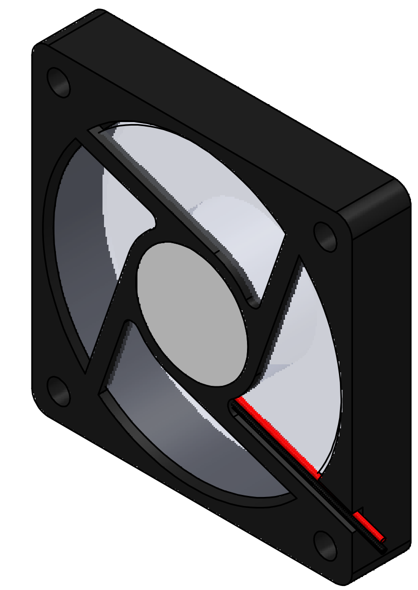
MATERIAL:

LASR
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
SPDT ROCKER SWITCH

PROJECT:	DWG NO.:		REV:
NEST	**10712**		0
DATE:	SIZE:	SCALE:	SHEET:
03/20/20	ANSI B	1:1	1 OF 1





SHEET NOTES:

1. A CAD MODEL FOR THIS PART WAS NOT AVAILABLE FROM THE MANUFACTURER. THE CAD MODEL FOR THIS DRAWING WAS CREATED USING EXTENT DIMENSIONS AND HOLE DIMENSIONS PROVIDED BY THE MANUFACTURER, AND INTERIOR DIMENSIONS WERE ESTIMATED USING VISUAL PROPORTIONS FROM PART IMAGES. THEREFORE, THE DRAWING FOR THIS PART SHOULD NOT BE CONSIDERED ACCURATE AND IS PROVIDED FOR REFERENCE ONLY.

ASSEMBLIES USED

NEXT ASM:	ASM DESCRIPTION:	QTY:
10550	SIDING LEFT ASSEMBLY	1

REVISION HISTORY

REV:	DATE:	DESCRIPTION:	DRAWN:
0	03/20/20	ORIGINAL THESIS DESIGN	A. SIMON

COMMENTS:

UNLESS OTHERWISE NOTED:
-- ALL DIMENSIONS IN MM

MATERIAL:

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LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

TITLE:
60MM COOLING FAN

PROJECT:	DWG NO.:		REV:
NEST	**10721**		0
DATE: 03/20/20	SIZE: ANSI B	SCALE: 1:1	SHEET: 1 OF 1

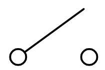
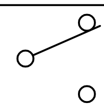
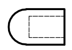
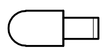
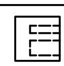
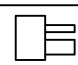
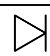
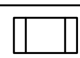
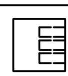
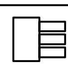
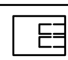
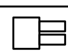
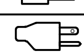
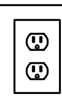
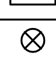
APPENDIX B

ELECTRICAL DRAWINGS

Contents

LEGEND

SYMBOLS

	1-POSITION SWITCH
	2-POSITION SWITCH
	BARREL CONNECTOR, FEMALE
	BARREL CONNECTOR, MALE
	CONTINUITY TO OTHER SHEET
	DEANS CONNECTOR, FEMALE
	DEANS CONNECTOR, MALE
	DIODE
	FUSE
	MR30 CONNECTOR, 3 POLE, FEMALE
	MR30 CONNECTOR, 3 POLE, MALE
	MR30 CONNECTOR, 2 POLE, FEMALE
	MR30 CONNECTOR, 2 POLE, MALE
	NEMA CONNECTOR
	RECEPTACLE
	TERMINAL

ABBREVIATIONS

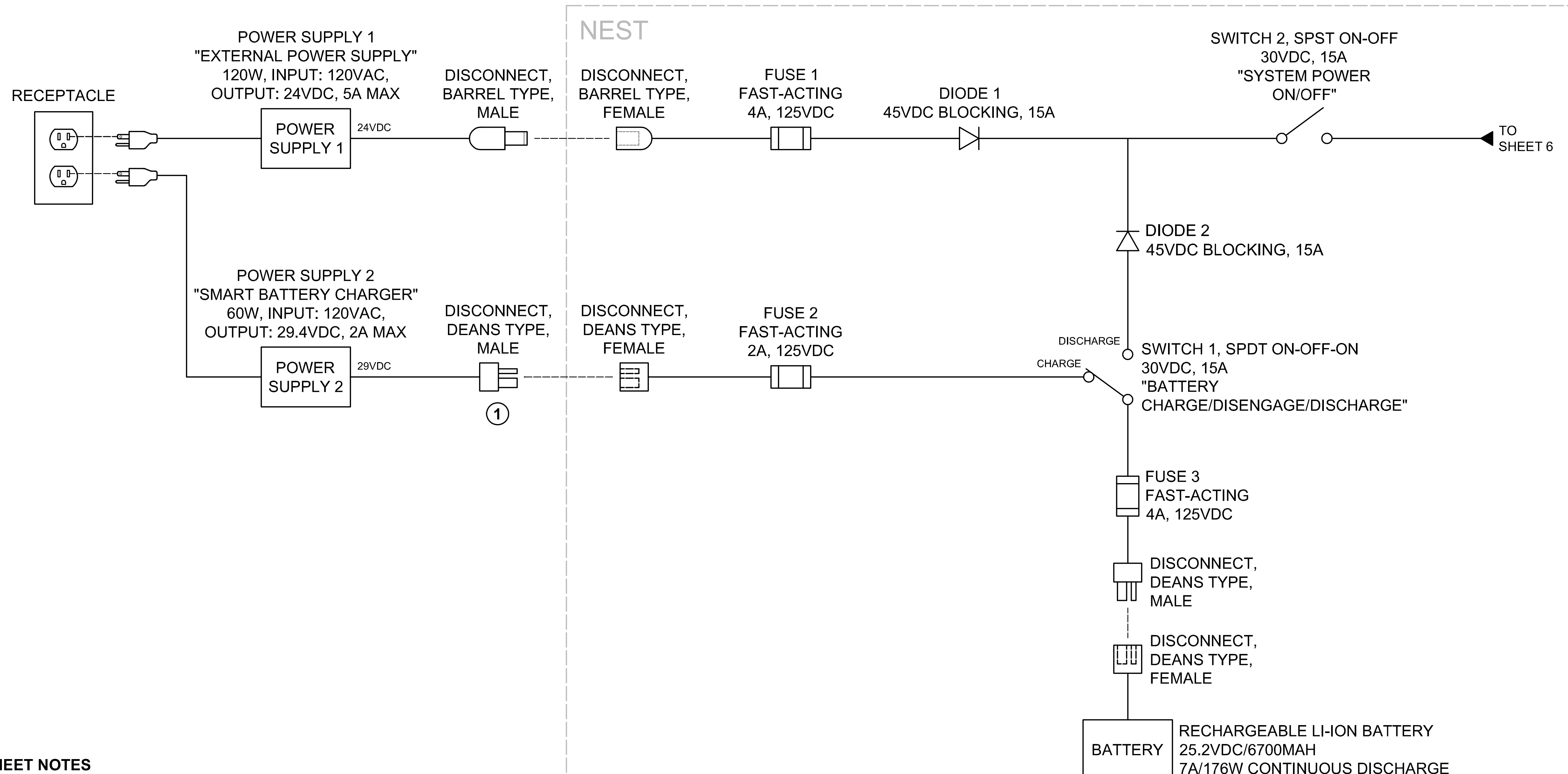
A	AMPERES
AC	ALTERNATING CURRENT
AVG	AVERAGE
CFM	CUBIC FEET PER MINUTE
CONT.	CONTINUOUS
CONV.	CONVERTER
DC	DIRECT CURRENT
GB	GIGABYTE
IMU	INERTIAL MEASUREMENT UNIT
MAH	MILLIAMPERE HOURS
MAX	MAXIMUM
MIN	MINIMUM
MM	MILLIMETERS
RAM	RANDOM-ACCESS MEMORY
SPDT	SINGLE POLE, DOUBLE THROW
SPST	SINGLE POLE, SINGLE THROW
SSD	SOLID STATE DRIVE
TI	TEXAS INSTRUMENTS
VAC	VOLTS ALTERNATING CURRENT
VDC	VOLTS DIRECT CURRENT
VN	VECTORNAV
W	WATTS

REVISIONS

ID	DATE	DESCRIPTION
0	03/20/20	AS-BUILT

LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

PROJECT:	TITLE:			
NEST	**LEGEND**			
DRAWN:	DATE:	SCALE:	REV:	SHEET:
A. SIMON	03/20/20		0	2



SHEET NOTES

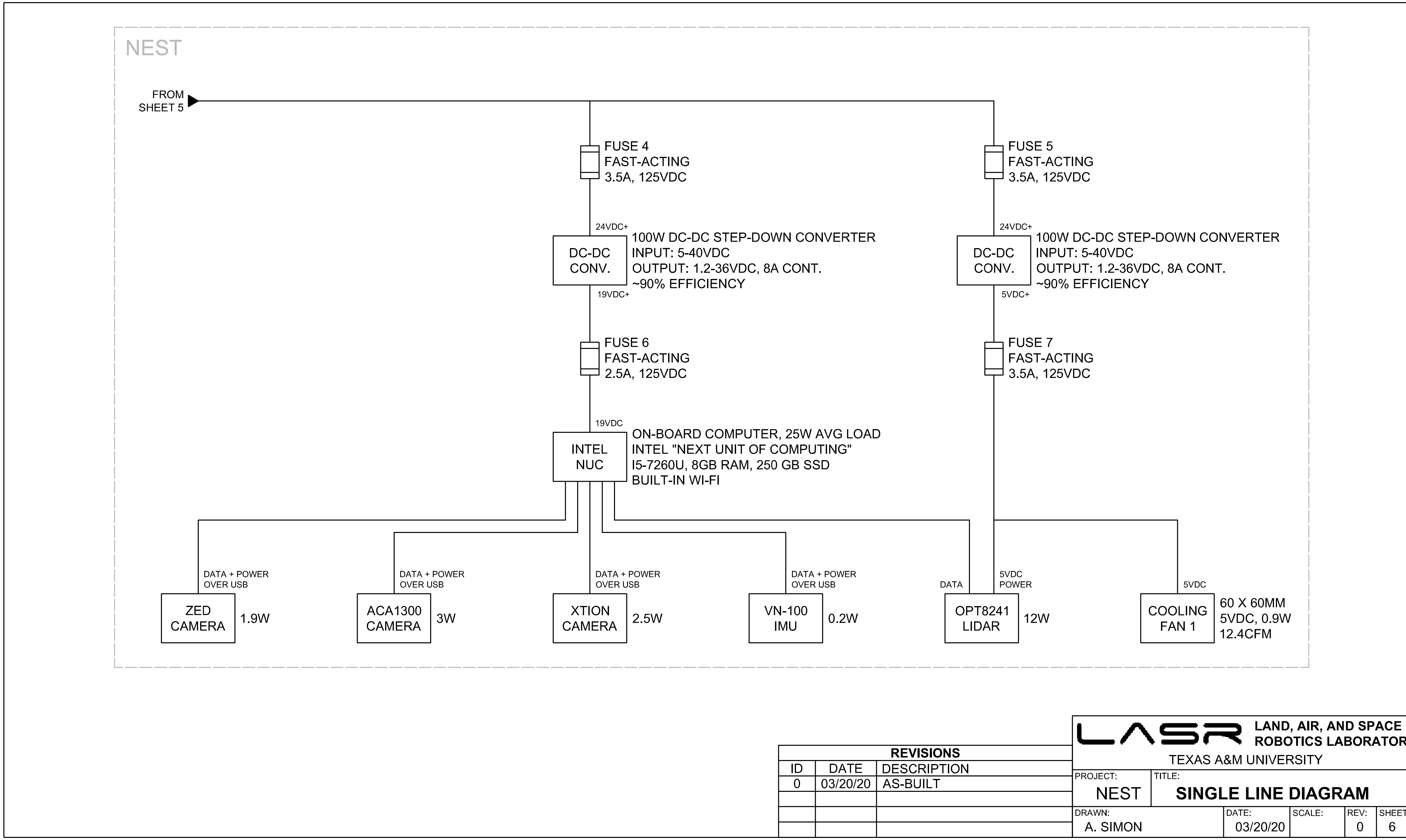
1. THE DEANS CONNECTOR ON POWER SUPPLY 2 - "SMART BATTERY CHARGER" WAS INTENTIONALLY MADE TO BE MALE AND NOT FEMALE, EVEN THOUGH THE EXPOSED LEADS OF A MALE CONNECTOR POSE A POTENTIAL HAZARD WHEN THE POWER SUPPLY IS ENERGIZED. THIS WAS DONE SO THAT THE POWER SUPPLY MAY BE DIRECTLY CONNECTED TO THE BATTERY'S FEMALE CONNECTOR IF THE USER DESIRES. THE USER IS RESPONSIBLE FOR CONNECTING THE POWER SUPPLY TO A FEMALE CONNECTOR BEFORE CONNECTING THE POWER SUPPLY TO A POWER SOURCE TO PREVENT THE BARE LEADS FROM BECOMING ENERGIZED.

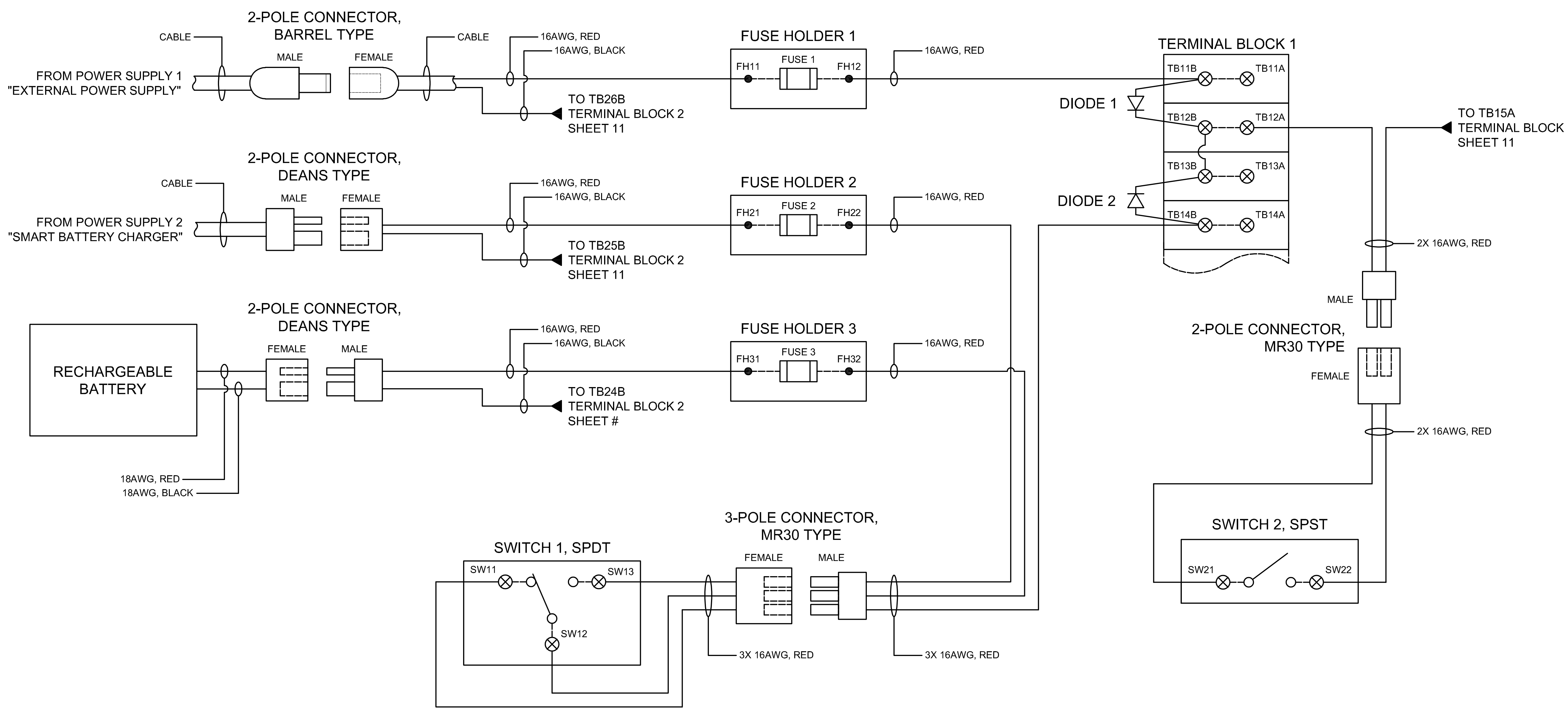
REVISIONS

ID	DATE	DESCRIPTION
0	03/20/20	AS-BUILT

LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

PROJECT:	TITLE:				
NEST	**SINGLE LINE DIAGRAM**				
DRAWN: A. SIMON		DATE: 03/20/20	SCALE:	REV: 0	SHEET: 5


NEST
FROM SHEET 5
FUSE 4
FAST-ACTING
3.5A, 125VDC
FUSE 5
FAST-ACTING
3.5A, 125VDC
24VDC+
DC-DC CONV.
100W DC-DC STEP-DOWN CONVERTER
INPUT: 5-40VDC
OUTPUT: 1.2-36VDC, 8A CONT.
~90% EFFICIENCY
19VDC+
24VDC+
DC-DC CONV.
100W DC-DC STEP-DOWN CONVERTER
INPUT: 5-40VDC
OUTPUT: 1.2-36VDC, 8A CONT.
~90% EFFICIENCY
5VDC+
FUSE 6
FAST-ACTING
2.5A, 125VDC
FUSE 7
FAST-ACTING
3.5A, 125VDC
19VDC
INTEL NUC
ON-BOARD COMPUTER, 25W AVG LOAD
INTEL "NEXT UNIT OF COMPUTING"
I5-7260U, 8GB RAM, 250 GB SSD
BUILT-IN WI-FI
DATA + POWER OVER USB
ZED CAMERA
1.9W
DATA + POWER OVER USB
ACA1300 CAMERA
3W
DATA + POWER OVER USB
XTION CAMERA
2.5W
DATA + POWER OVER USB
VN-100 IMU
0.2W
DATA
5VDC POWER
OPT8241 LIDAR
12W
5VDC
COOLING FAN 1
60 X 60MM
5VDC, 0.9W
12.4CFM
REVISIONS
ID
DATE
DESCRIPTION
0
03/20/20
AS-BUILT
LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY
PROJECT:
NEST
TITLE:
SINGLE LINE DIAGRAM
DRAWN:
A. SIMON
DATE:
03/20/20
SCALE:
REV:
0
SHEET:
6



REVISIONS		
ID	DATE	DESCRIPTION
0	03/20/20	AS-BUILT

LASR — LAND, AIR, AND SPACE ROBOTICS LABORATORY
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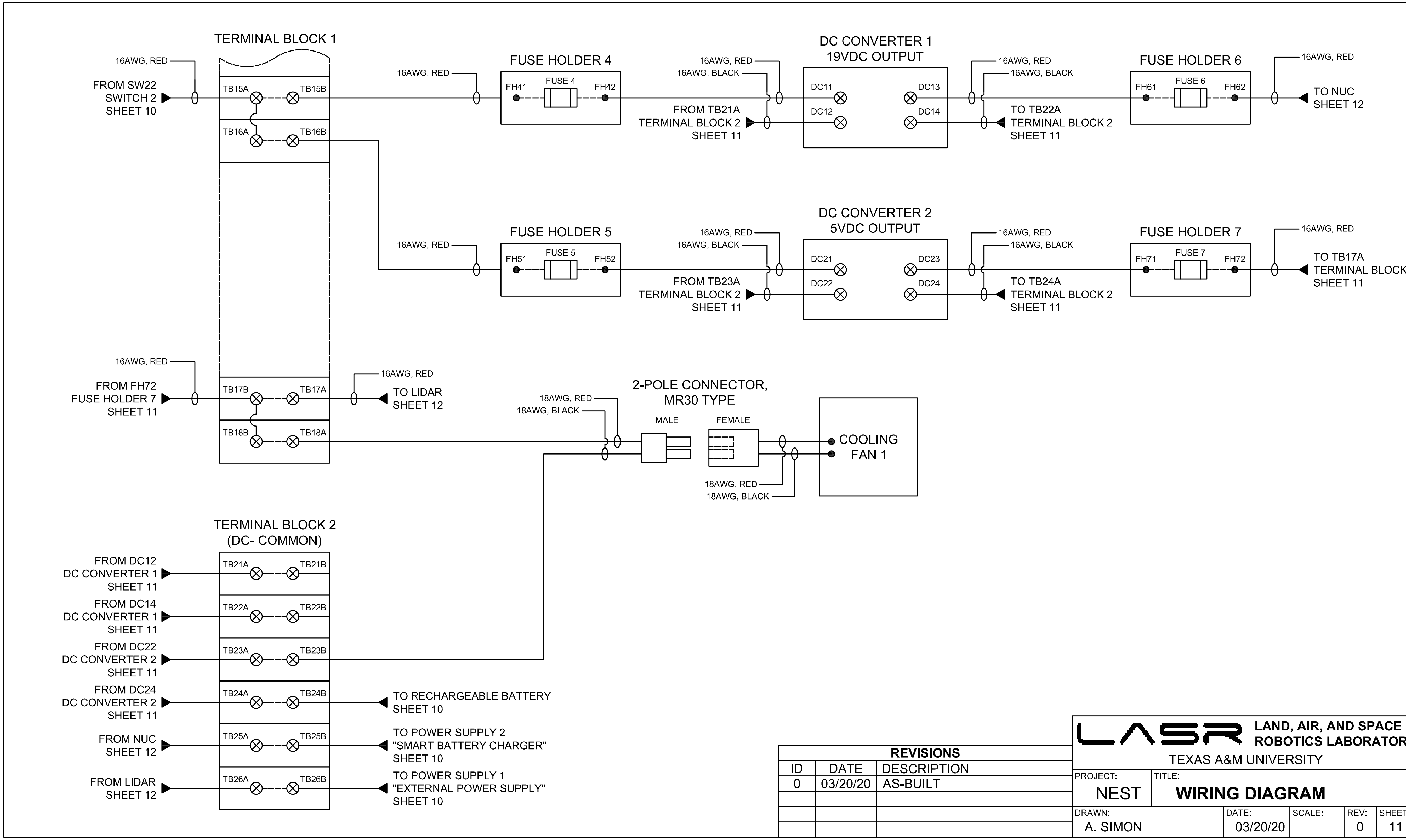
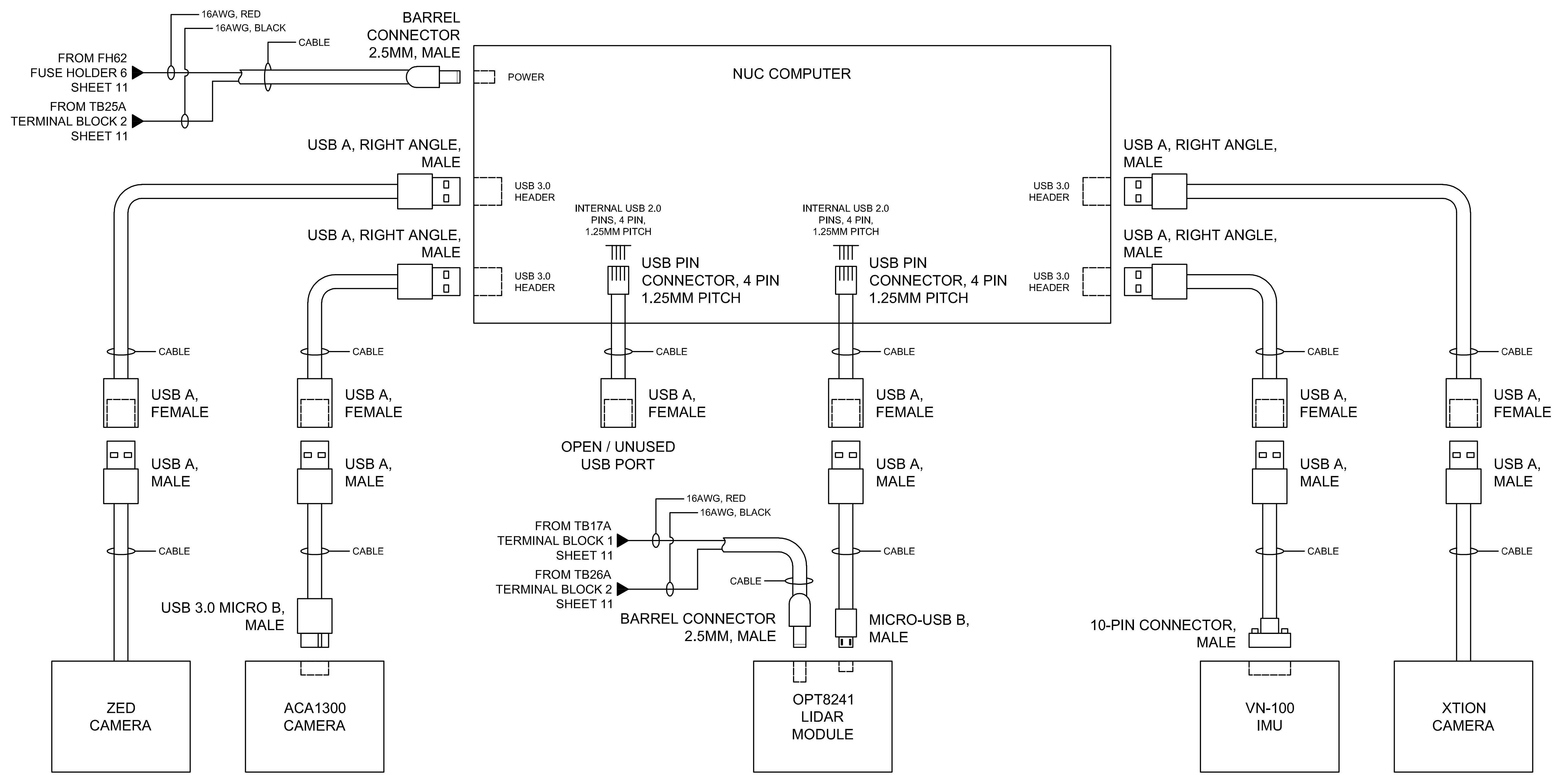
PROJECT:	TITLE:			
NEST	**WIRING DIAGRAM**			
DRAWN: A. SIMON	DATE: 03/20/20	SCALE:	REV: 0	SHEET: 10


TERMINAL BLOCK 1
16AWG, RED
FROM SW22
SWITCH 2
SHEET 10
TB15A
TB15B
TB16A
TB16B
FUSE HOLDER 4
16AWG, RED
FH41
FUSE 4
FH42
16AWG, RED
16AWG, BLACK
FROM TB21A
TERMINAL BLOCK 2
SHEET 11
DC CONVERTER 1
19VDC OUTPUT
DC11
DC12
DC13
DC14
16AWG, RED
16AWG, BLACK
TO TB22A
TERMINAL BLOCK 2
SHEET 11
FUSE HOLDER 6
FH61
FUSE 6
FH62
16AWG, RED
TO NUC
SHEET 12
FUSE HOLDER 5
16AWG, RED
FH51
FUSE 5
FH52
16AWG, RED
16AWG, BLACK
FROM TB23A
TERMINAL BLOCK 2
SHEET 11
DC CONVERTER 2
5VDC OUTPUT
DC21
DC22
DC23
DC24
16AWG, RED
16AWG, BLACK
TO TB24A
TERMINAL BLOCK 2
SHEET 11
FUSE HOLDER 7
FH71
FUSE 7
FH72
16AWG, RED
TO TB17A
TERMINAL BLOCK 1
SHEET 11
16AWG, RED
FROM FH72
FUSE HOLDER 7
SHEET 11
TB17B
TB17A
TB18B
TB18A
16AWG, RED
TO LIDAR
SHEET 12
2-POLE CONNECTOR,
MR30 TYPE
18AWG, RED
18AWG, BLACK
MALE
FEMALE
18AWG, RED
18AWG, BLACK
COOLING
FAN 1
TERMINAL BLOCK 2
(DC- COMMON)
FROM DC12
DC CONVERTER 1
SHEET 11
TB21A
TB21B
FROM DC14
DC CONVERTER 1
SHEET 11
TB22A
TB22B
FROM DC22
DC CONVERTER 2
SHEET 11
TB23A
TB23B
FROM DC24
DC CONVERTER 2
SHEET 11
TB24A
TB24B
TO RECHARGEABLE BATTERY
SHEET 10
FROM NUC
SHEET 12
TB25A
TB25B
TO POWER SUPPLY 2
"SMART BATTERY CHARGER"
SHEET 10
FROM LIDAR
SHEET 12
TB26A
TB26B
TO POWER SUPPLY 1
"EXTERNAL POWER SUPPLY"
SHEET 10
REVISIONS
ID
DATE
DESCRIPTION
0
03/20/20
AS-BUILT
LASR
LAND, AIR, AND SPACE
ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY
PROJECT:
NEST
TITLE:
WIRING DIAGRAM
DRAWN:
A. SIMON
DATE:
03/20/20
SCALE:
REV:
0
SHEET:
11

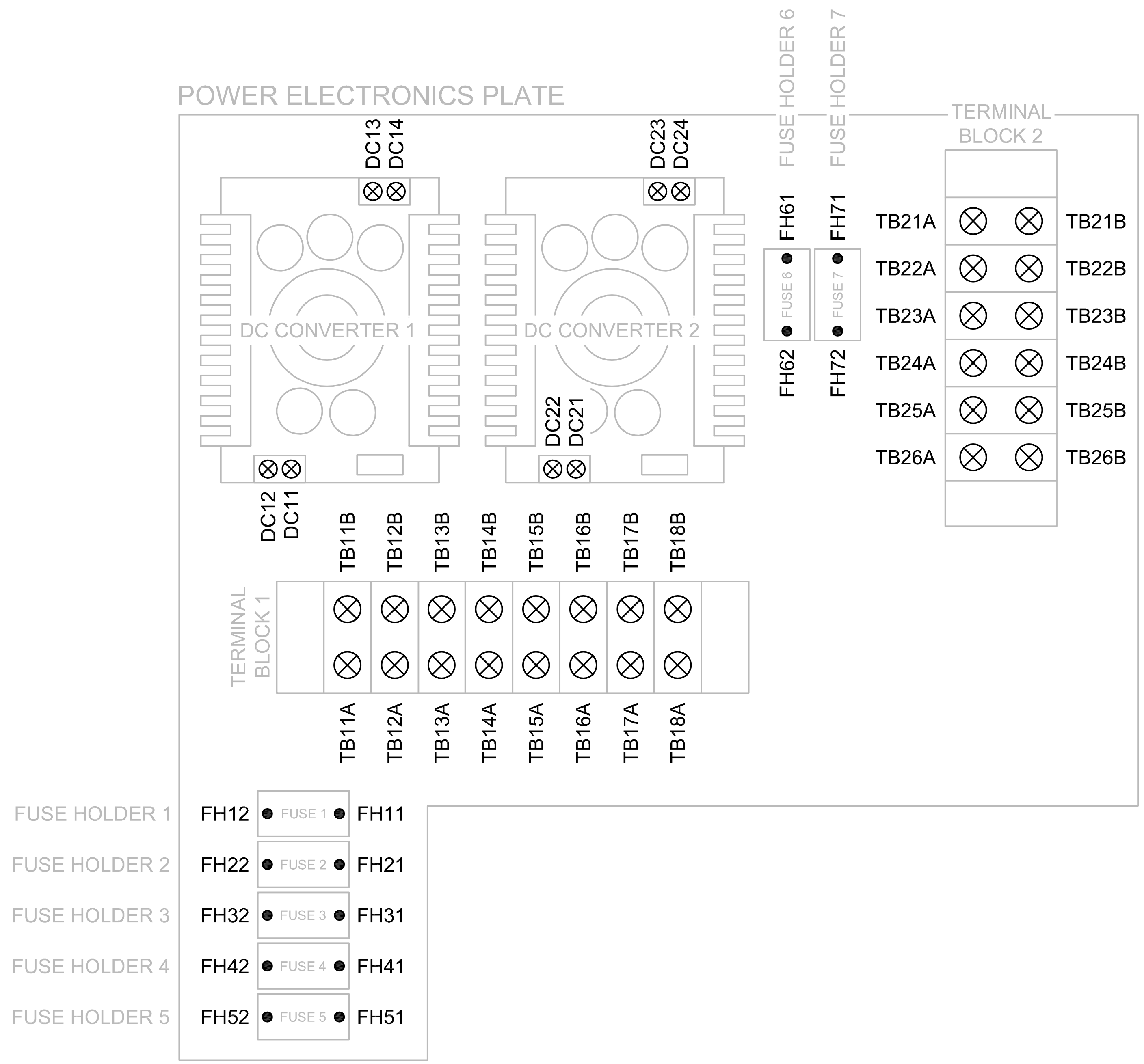


REVISIONS

ID	DATE	DESCRIPTION
0	03/20/20	AS-BUILT

LASR LAND, AIR, AND SPACE ROBOTICS LABORATORY
TEXAS A&M UNIVERSITY

PROJECT:	TITLE:			
NEST	**WIRING DIAGRAM**			
DRAWN: A. SIMON	DATE: 03/20/20	SCALE:	REV: 0	SHEET: 12



REVISIONS

ID	DATE	DESCRIPTION
0	03/20/20	AS-BUILT

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PROJECT:	TITLE:				
NEST	**COMPONENT LAYOUT**				
DRAWN:		DATE:	SCALE:	REV:	SHEET:
A. SIMON		03/20/20		0	15

APPENDIX C

SAMPLE COMPUTER CODE

Contents

Example IMU Data Publisher


```cpp
/*%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
IMU Data Publisher (for VectorNav Inertial Measurement Units)
Author: Andrew B. Simon
Land, Air, & Space Robotics Laboratory, Texas A&M University
Last Modified: 09/20/2019

Functional Summary:
  This program connects to a VectorNav sensor which is connected to the host
computer via USB, continuously polls the sensor for acceleration and angular
rate measurements - along with their variances - and continuously broadcasts the
time-stamped measurements and variances over the network using standard Robot
Operating System (ROS) messages.

Additional Information:
  -- Measurements are time-stamped with time since epoch (midnight, January 1,
     1970) to nanosecond precision.
  -- Connection to the sensor is first attempted at a user defined baud rate. If
     connection was not successfully established at the user defined baud rate,
     a second connection attempt is made at the factory default baud rate. If a
     successful connection is made at the factory default baud rate, the baud
     rate is automatically changed to the user defined baud rate.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%*/

// standard includes
#include <iostream>
#include <iomanip>
#include <chrono>

// include these headers to get access to core ROS functionality and the
// specific ROS message type this node will broadcast (sensor_msgs::Imu)
#include "ros/ros.h"
#include "sensor_msgs/Imu.h"

// include this header file to get access to VectorNav sensors
#include "vn/sensors.h"

// setup namespaces
using namespace vn::sensors;
using namespace vn::protocol::uart;

int main(int argc, char **argv)
{
  // initialize ROS and define a unique name for this node
  ros::init(argc, argv, "NEST_IMU_Publisher");

  // create a handle to this ROS node
  ros::NodeHandle nh;

  // define a new ROS publisher to inform the master ROS node that this node
  // will be publishing messages of type sensor_msgs::Imu on the topic
  // "NEST_IMU_meas" with a 1000 message output buffer
  ros::Publisher NEST_IMU_pub = nh.advertise<sensor_msgs::Imu>("NEST_IMU_meas", 1000);

  // designate the maximum node loop rate as 100 hertz
  ros::Rate loop_rate(100);

```

```
// Linux format for virtual (USB) serial port
  const std::string SensorPort = "/dev/ttyUSB0";

// define the factor default and user designated baud rates for the sensor
  const uint32_t defaultBaudRate = 115200 ; // factory default baud rate
  const uint32_t sensorBaudRate = 921600  ; // user-defined baud rate

// create a VectorNav sensor object
  VnSensor vs;

// attempt connection to the sensor using the user defined baud rate
  std::cout << "Attempting to connect to IMU using user specified baud rate ("
     << sensorBaudRate << ")..." << std::endl;
  vs.connect(SensorPort, sensorBaudRate);

// verify connection to the sensor. If successful, output diagnostic information
  if (vs.verifySensorConnectivity()) {
  // output diagnostic information
      std::cout << "Successfully connected to IMU using user specified baud rate!" << std::endl
                << "  Model Number: " << vs.readModelNumber() << std::endl
                    << "  Serial Number: " << vs.readSerialNumber() << std::endl
                    << "  Firmware Version: " << vs.readFirmwareVersion() << std::endl
                    << "  Port: " << vs.port() << std::endl
                    << "  Baud Rate: " << vs.readSerialBaudRate() << std::endl;
  }
// if the connection to the sensor using the user defined baud rate was
// unsuccessful, attempt connection using the factory default baud rate.
  else {
  // attempt connection using the factory default baud rate
      std::cout << "Attempting to connect to IMU using factory default baud rate ("
            << defaultBaudRate << ")..." << std::endl;
      vs.connect(SensorPort, defaultBaudRate);

  // verify connection to the sensor. If successful, output diagnostic
  // information and attempt to change the sensor baud rate to the user
  // defined baud rate
      if (vs.verifySensorConnectivity()) {
    // output diagnostic information
          std::cout << "Successfully connected to IMU using factory default baud rate!" << std::endl
                    << "  Model Number: " << vs.readModelNumber() << std::endl
                        << "  Serial Number: " << vs.readSerialNumber() << std::endl
                        << "  Firmware Version: " << vs.readFirmwareVersion() << std::endl
                        << "  Port: " << vs.port() << std::endl
                        << "  Baud Rate: " << vs.readSerialBaudRate() << std::endl;

         // change the sensor baud rate to the user defined baud rate
         std::cout << "Attempting to change baud rate to " << sensorBaudRate << "..." << std::endl;
                   vs.changeBaudRate(sensorBaudRate);

         // output the new baud rate for verification
                   std::cout << "Baud rate is now " << vs.readSerialBaudRate() << "!" << std::endl;
      }
  // if connection to the sensor was unsuccessful via both the user defined
  // and factory default baud rates, output diagnostic information and shut
  // down the node
      else {
```

```
            std::cout << "Failed to connect to IMU!" << std::endl;
            return(-1);
        }
    }

    // declare a measurement (gravity included) register. Comment out if using
    // YawPitchRollTrueBodyAccelerationAndAngularRatesRegister (gravity removed)
    // instead
    //YawPitchRollMagneticAccelerationAndAngularRatesRegister measurementRegister;

    // declare a measurement (gravity removed) register. Comment out if using
    // YawPitchRollMagneticAccelerationAndAngularRatesRegister (gravity included)
    // instead
      YawPitchRollTrueBodyAccelerationAndAngularRatesRegister trueMeasurementRegister;

    // declare a measurement variance register
      FilterMeasurementsVarianceParametersRegister varianceRegister;

    // declare an integer to store and increment the message sequence number
    uint32_t count = 1;

    while (ros::ok())
    {
      // declare a ROS message of type sensor_msgs::Imu
      sensor_msgs::Imu imu_meas;

      // read the measurement variance
      varianceRegister = vs.readFilterMeasurementsVarianceParameters();

      // read the gravity-included accelerations and angular rates. Comment out if
      // using the trueMeasurementRegister instead
      //measurementRegister = vs.readYawPitchRollMagneticAccelerationAndAngularRates();

      // read the gravity-removed accelerations and angular rates. Comment out if
      // using the measurementRegister instead
      trueMeasurementRegister = vs.readYawPitchRollTrueBodyAccelerationAndAngularRates();

      // get the current system time, convert it to a duration since epoch, and
      // represent it in whole seconds and nanoseconds forms
      auto now = std::chrono::system_clock::now(); // current system time
      auto time = now.time_since_epoch(); // duration since epoch
      auto time_s = std::chrono::duration_cast<std::chrono::seconds>(time); // represented as whole seconds
      auto time_ns = std::chrono::duration_cast<std::chrono::nanoseconds>(time); //represented as whole nanoseconds

      // output the current measurement sequence and time stamp for user verification purposes
      std::cout << "Sequence: " << count << "\tTime: " << std::setprecision(19) << time_ns.count()/1e9 << std::endl;

      // populate the message header
      imu_meas.header.seq = count;  //  the sequence of the measurement (measurement count)
      imu_meas.header.stamp.sec = time_s.count();  // the whole seconds component of the measurement time stamp
      imu_meas.header.stamp.nsec = (time_ns.count()-time_s.count()*1e9);  // the nanoseconds component of the measurement time stamp
      imu_meas.header.frame_id = "NEST_IMU_frame";  //  the frame ID of the measurement (sensor frame)

      // set the first element of the orientation covariance to -1 so subscribers know we are not
```

```
        including
    // orientation data in the message
    imu_meas.orientation_covariance[0] = -1;

    // populate the angular velocity vector portion of the message. Comment out
    // if using trueMeasurementRegister instead
    //imu_meas.angular_velocity.x = measurementRegister.gyro[0];
    //imu_meas.angular_velocity.y = measurementRegister.gyro[1];
    //imu_meas.angular_velocity.z = measurementRegister.gyro[2];

    // populate the angular velocity vector portion of the message. Comment out
    // if using measurementRegister instead
    imu_meas.angular_velocity.x = trueMeasurementRegister.gyro[0];
    imu_meas.angular_velocity.y = trueMeasurementRegister.gyro[1];
    imu_meas.angular_velocity.z = trueMeasurementRegister.gyro[2];

    // populate the angular velocity covariance matrix portion of the message
    imu_meas.angular_velocity_covariance = { varianceRegister.angularRateVariance[0], 0, 0,
                                                                    0,
                        varianceRegister.angularRateVariance[1], 0,
                                                                    0, 0,
                        varianceRegister.angularRateVariance[2] };

    // populate the linear acceleration vector portion of the message. Comment
    // out if using trueMeasurementRegister instead
    //imu_meas.linear_acceleration.x = measurementRegister.bodyAccel[0];
    //imu_meas.linear_acceleration.y = measurementRegister.bodyAccel[1];
    //imu_meas.linear_acceleration.z = measurementRegister.bodyAccel[2];

    // populate the linear acceleration vector portion of the message. Comment
    // out if using measurementRegister instead
    imu_meas.linear_acceleration.x = trueMeasurementRegister.bodyAccel[0];
    imu_meas.linear_acceleration.y = trueMeasurementRegister.bodyAccel[1];
    imu_meas.linear_acceleration.z = trueMeasurementRegister.bodyAccel[2];

    // populate the linear acceleration covariance matrix portion of the message
    imu_meas.linear_acceleration_covariance = { varianceRegister.accelerationVariance[0], 0, 0,
                                                                           0,
                        varianceRegister.accelerationVariance[1], 0,
                                                                           0, 0,
                        varianceRegister.accelerationVariance[2] };

    // publish the message and increment the message count
    NEST_IMU_pub.publish(imu_meas);
    count++;

    // sleep for any remaining time in the period defined by the node loop rate
    loop_rate.sleep();
  }

    // disconnect from the sensor
    vs.disconnect();

    // end of program
    return 0;
  }
```

Example IMU Data Logger


```cpp
/*%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
IMU Data Logger
Author: Andrew B. Simon
Land, Air, & Space Robotics Laboratory, Texas A&M University
Last Modified: 09/20/2019

Functional Summary:
  This program receives IMU (inertial measurement unit) acceleration and angular
rate measurement data - along with the measurement variances, writes the data to
a file, and outputs the data for diagnostic purposes. Data is received over the
network using standard Robot Operating System (ROS) messages.

Additional Information:
  -- Measurements are time-stamped with time since epoch (midnight, January 1,
     1970) to nanosecond precision. Note: time stamp is per the IMU host machine
     NOT the machine running this code.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%*/

// standard includes
#include <fstream>
#include <iomanip>
#include <iostream>

// include these headers to get access to core ROS functionality and the
// specific ROS message type this node will receive (sensor_msgs::Imu)
#include "ros/ros.h"
#include "sensor_msgs/Imu.h"

// open a file stream to file where measurement data will be written
std::ofstream IMUdatafile ("/home/nestuser/IMUdatalog.txt");

// a callback function which is executed whenever a new message is received on
// the subscribed topic "NEST_IMU_meas". This function parses data out of the
// sensor_msgs::Imu message, writes the data to a data log file, and outputs
// diagnostic data
void callback(const sensor_msgs::Imu::ConstPtr& msg)
 {

   // write the message sequence, measurement time, accelerations, angular
   // rates, and measurement variances to the data log file
   IMUdatafile << msg->header.seq << ","
               << std::setprecision(19) << std::fixed << (msg->header.stamp.sec + msg->header.stamp.nsec/1e9) << ","
               << std::setprecision(3) << std::fixed << msg->linear_acceleration.x << ","
               << msg->linear_acceleration.y << ","
               << msg->linear_acceleration.z << ","
               << std::setprecision(4) << std::fixed << msg->angular_velocity.x << ","
               << msg->angular_velocity.y << ","
               << msg->angular_velocity.z << ","
               << std::setprecision(6) << std::fixed << msg->linear_acceleration_covariance[0] << ","
               << msg->linear_acceleration_covariance[4] << ","
               << msg->linear_acceleration_covariance[8] << ","
               << std::setprecision(8) << std::fixed << msg->angular_velocity_covariance[0] << ","
               << msg->angular_velocity_covariance[4] << ","
```

```
                << msg->angular_velocity_covariance[8] << std::endl;

    // output the message sequence, measurement time, accelerations, and angular
    // rates for diagnostic purposes
    std::cout << "Seq: " << msg->header.seq
              << "\tTime: " << std::setprecision(19) << std::fixed << (msg->header.stamp.sec + msg->header.stamp.nsec/1e9)
              << "\tAccel: " << std::setprecision(3) << std::fixed << msg->linear_acceleration.x << ","
              << msg->linear_acceleration.y << ","
              << msg->linear_acceleration.z << ","
              << "\tAng Rate: " << std::setprecision(4) << std::fixed << msg->angular_velocity.x << ","
              << msg->angular_velocity.y << ","
              << msg->angular_velocity.z << std::endl;
 }

int main(int argc, char **argv)
 {

    // initialize ROS and define a unique name for this node
    ros::init(argc, argv, "NEST_IMU_listener");

    // create a handle to this ROS node
    ros::NodeHandle nh;

    // define a new ROS subscriber to inform the master ROS node that this node
    // will be receiving messages on the topic "NEST_IMU_meas" with a 1000
    // message input buffer. Register the callback function "callback" to execute
    // when a new message is received
    ros::Subscriber sub = nh.subscribe("NEST_IMU_meas", 1000, callback);

    // write file header information to the data log file
    IMUdatafile << "time,accel1,accel2,accel3,angrate1,angrate2,angrate3,accel1var,accel2var,accel3var,angrate1var,angrate2var,angrate3var" << std::endl;

    // put this node into a spin state until the node is shutdown, forever
    // looping and continuously pumping callbacks when messages are received
    ros::spin();

    // close the data log file
    IMUdatafile.close();

   // end of program
    return 0;
 }
```

Example Camera Image Publisher


```cpp
/*%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
ZED Image Publisher (for Stereolabs ZED Camera)
Author: Andrew B. Simon
Land, Air, & Space Robotics Laboratory, Texas A&M University
Last Modified: 09/21/2019

Functional Summary:
  This program connects to a ZED camera which is connected to the host
computer via USB, calibrates the camera using a calibration file specific to the
camera serial number, initiates video capture using OpenCV, captures images, and
broadcasts the image stream over the network using Robot Operating System (ROS)
messages.

Additional Information:
  -- This node can be configured to broadcast an image stream from either the
     left camera, right camera, or both (stereo).
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%*/

// standard includes
#include <iostream>
#include <string>
#include <chrono>

// OpenCV includes
#include <opencv2/opencv.hpp>

// ZED includes for camera calibration
#include "calibration.hpp"

// include this header to get access to core ROS functionality
#include <ros/ros.h>

// include these headers to transmit OpenCV images using ROS messages
#include <image_transport/image_transport.h>
#include <cv_bridge/cv_bridge.h>

// the camera output mode. "left" for left camera, "right" for right camera,
// "stereo" for both cameras
std::string outputMode = "stereo";

int main(int argc, char** argv)
{
  // the image size in pixels
  cv::Size2i image_size = cv::Size2i(1280, 720); // max size (2208,1242)

  std::string calibration_file;
  unsigned int serial_number = 19449;

  // Download camera calibration file
  if (downloadCalibrationFile(serial_number, calibration_file)) return 1;
  std::cout << "Calibration file found. Loading..." << std::endl;

  // calibrate camera
  cv::Mat map_left_x, map_left_y;
  cv::Mat map_right_x, map_right_y;
  cv::Mat cameraMatrix_left, cameraMatrix_right;
```

```
initCalibration(calibration_file, image_size, map_left_x, map_left_y, map_right_x, map_right_y, cameraMatrix_left, cameraMatrix_right);

// output the camera matricies
std::cout << " Camera Matrix L: \n" << cameraMatrix_left << std::endl << std::endl;
std::cout << " Camera Matrix R: \n" << cameraMatrix_right << std::endl << std::endl;

// initiate video capture
cv::VideoCapture cap(0);
if (!cap.isOpened()){
  std::cout << "Video capture not successfully opened!" << std::endl;
      return -1;
  }
std::cout << "Video capture successfully opened!" << std::endl;
cap.grab();

// Set the video resolution (2*Width * Height) and frame rate
cap.set(CV_CAP_PROP_FRAME_WIDTH, image_size.width * 2);
cap.set(CV_CAP_PROP_FRAME_HEIGHT, image_size.height);
cap.set(CV_CAP_PROP_FPS, 15);
cap.grab();

// initialize ROS and define a unique name for this node
ros::init(argc, argv, "ZED_Publisher");

// create a handle to this ROS node
ros::NodeHandle nh;

// define new ROS publishers to inform the master ROS node that this node
// will be publishing image messages on the topics "NEST_ZED/left_image",
// "NEST_ZED/right_image", and "NEST_ZED/stereo_image"
image_transport::ImageTransport it(nh);
image_transport::Publisher NEST_ZED_left_pub = it.advertise("NEST_ZED/left_image",1);
image_transport::Publisher NEST_ZED_right_pub = it.advertise("NEST_ZED/right_image",1);
image_transport::Publisher NEST_ZED_stereo_pub = it.advertise("NEST_ZED/stereo_image",1);

// declare an integer to store and increment the message sequence number
uint32_t count = 1;

// designate the maximum node loop rate as 15 hertz
int roslr = 15;
ros::Rate loop_rate(roslr);
std::cout << "ROS loop rate set to " << roslr << std::endl << std::endl;

while (ros::ok())
{
  // get a new stereo image frame from the camera
  cv::Mat stereoImg_raw;
  cap >> stereoImg_raw;

  // get the current system time, convert it to a duration since epoch, and
  // represent it in whole seconds and nanoseconds forms
  auto now = std::chrono::system_clock::now(); // current system time
  auto time = now.time_since_epoch(); // duration since epoch
  auto time_s = std::chrono::duration_cast<std::chrono::seconds>(time); // represented as whole seconds
  auto time_ns = std::chrono::duration_cast<std::chrono::nanoseconds>(time); //represented as whole nanoseconds

  // check if the grabbed frame is empty. If it is populated, publish the frame
```

```cpp
    if(!stereoImg_raw.empty())
    {
      // output diagnostic information
      std::cout << "Captured ZED image frame " << count << ".\tTime: " << std::setprecision(19) << time_ns.count()/1e9 << std::endl;

      // declare and populate a temporary header message
      std_msgs::Header msgHeader;
      msgHeader.seq = count; // the sequence of the image (image count)
      msgHeader.stamp.sec = time_s.count();  // the whole seconds component of the measurement time stamp
      msgHeader.stamp.nsec = (time_ns.count()-time_s.count()*1e9);  // the nanoseconds component of the measurement time stamp

      if (outputMode == "left")
      {
          // declare a ROS sensor_msgs::ImagePtr message
          sensor_msgs::ImagePtr leftImgPtr;

          // declare new OpenCV images
          cv::Mat leftImg_raw, leftImg_rect;

          // extract the raw left image from the raw stereo image
          leftImg_raw = stereoImg_raw(cv::Rect(0, 0, stereoImg_raw.cols / 2, stereoImg_raw.rows));

          // rectify the raw left image
          cv::remap(leftImg_raw, leftImg_rect, map_left_x, map_left_y, cv::INTER_LINEAR);

          // populate the frame ID of the temporary header message
          msgHeader.frame_id = "ZED_left_camera";  // the frame ID of the image (sensor frame)

          // convert the OpenCV image to a ROS message compatible type using cv_bridge
          leftImgPtr = cv_bridge::CvImage(msgHeader, "bgr8", leftImg_rect).toImageMsg();

          // publish the rectified left image
          NEST_ZED_left_pub.publish(leftImgPtr);
        }
      else if  (outputMode == "right")
      {
          // declare a ROS sensor_msgs::ImagePtr message
          sensor_msgs::ImagePtr rightImgPtr;

          // declare new OpenCV images
          cv::Mat rightImg_raw, rightImg_rect;

          // extract the raw right image from the raw stereo image
          rightImg_raw = stereoImg_raw(cv::Rect(stereoImg_raw.cols / 2, 0, stereoImg_raw.cols / 2, stereoImg_raw.rows));

          // rectify the raw right image
          cv::remap(rightImg_raw, rightImg_rect, map_right_x, map_right_y, cv::INTER_LINEAR);

          // populate the frame ID of the temporary header message
          msgHeader.frame_id = "ZED_right_camera";  // the frame ID of the image (sensor frame)

          // convert the OpenCV image to a ROS message compatible type using cv_bridge
          rightImgPtr = cv_bridge::CvImage(msgHeader, "bgr8", rightImg_rect).toImageMsg();

          // publish the rectified right image
```

```
          NEST_ZED_right_pub.publish(rightImgPtr);
        }
      else if (outputMode == "stereo")
      {
          // declare a ROS sensor_msgs::ImagePtr message
          sensor_msgs::ImagePtr stereoImgPtr;

          // declare new OpenCV images
          cv::Mat leftImg_raw, rightImg_raw, leftImg_rect, rightImg_rect;

          // extract the raw left and right images from the raw stereo image
          leftImg_raw = stereoImg_raw(cv::Rect(0, 0, stereoImg_raw.cols / 2, stereoImg_raw.rows));
          rightImg_raw = stereoImg_raw(cv::Rect(stereoImg_raw.cols / 2, 0, stereoImg_raw.cols / 2, stereoImg_raw.rows));

          // rectify the raw left and right images
          cv::remap(leftImg_raw, leftImg_rect, map_left_x, map_left_y, cv::INTER_LINEAR);
          cv::remap(rightImg_raw, rightImg_rect, map_right_x, map_right_y, cv::INTER_LINEAR);

          // declare a stereo image placeholder for recombining the left and right rectified images
          cv::Mat stereoImg_rect(leftImg_rect.rows, (leftImg_rect.cols+rightImg_rect.cols), CV_8UC3);

          // declare placeholders for the pixel areas corresponding to the left and right images within the stereo image
          cv::Mat stereoRect_leftImg = stereoImg_rect(cv::Range(0,leftImg_rect.rows), cv::Range(0,leftImg_rect.cols));
          cv::Mat stereoRect_rightImg = stereoImg_rect(cv::Range(0,rightImg_rect.rows), cv::Range(leftImg_rect.cols,leftImg_rect.cols+rightImg_rect.cols));

          //  copy the left and right rectified images into their respective location within the stereo image
          leftImg_rect.copyTo(stereoRect_leftImg);
          rightImg_rect.copyTo(stereoRect_rightImg);

          // populate the frame ID of the temporary header message
          msgHeader.frame_id = "ZED_stereo_camera";  // the frame ID of the image (sensor frame)

          // convert the OpenCV image to a ROS message compatible type using cv_bridge
          stereoImgPtr = cv_bridge::CvImage(msgHeader, "bgr8", stereoImg_rect).toImageMsg();

          // publish the rectified stereo pair
          NEST_ZED_stereo_pub.publish(stereoImgPtr);
      }

      // increment the image count
      count++;
    }

    // sleep for any remaining time in the period defined by the node loop rate
    loop_rate.sleep();
  }

  // end of program
  return 0;
}
```

Example Camera Image Logger


```cpp
/*%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
ZED Image Logger
Author: Andrew B. Simon
Land, Air, & Space Robotics Laboratory, Texas A&M University
Last Modified: 09/20/2019

Functional Summary:
  This program receives images from a ZED camera image stream, writes the images
  to files, and records the image time stamps in a log file. Images are received
  over the network using standard Robot Operating System (ROS) messages and are
  decoded into OpenCV images before saving.

 Additional Information:
  -- Images are time-stamped with time since epoch (midnight, January 1, 1970)
     to nanosecond precision. Note: time stamp is per the camera host machine
     NOT the machine running this code.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%*/

// standard includes
#include <fstream>
#include <iostream>
#include <stdio.h>
#include <string>

// OpenCV includes
#include <opencv2/opencv.hpp>
//#include <opencv2/highgui/highgui.hpp>

// include this header to get access to core ROS functionality
#include <ros/ros.h>

// include these headers to receive OpenCV images using ROS messages
#include <image_transport/image_transport.h>
#include <cv_bridge/cv_bridge.h>

// open a file stream to file where image time stamp data will be written
std::ofstream ImageDataFile("/home/nestuser/ImageTimeStamps.txt");

// a callback function which is executed whenever a new message is received on
// the subscribed topic "NEST_ZED/left_image". This function decodes the image
// from the message and records it to a file. The image time stamp is recorded
// to the time stamp data log file.
void leftImageCallback(const sensor_msgs::ImageConstPtr& lmsg)
{
  try
  {
    // decode the image from the message
    cv::Mat left_rect = cv_bridge::toCvShare(lmsg, "bgr8")->image;
    cv::waitKey(1);

    // create a unique file name for this image and write the image to a file
    std::string filename = "/home/nestuser/Rectified_Image_Log/L" + std::to_string(lmsg->header.seq) + ".ppm";
    cv::imwrite(filename,left_rect);

    // parse the image time stamp from the message and write it to the time
```

```
    // stamp data log file
    ImageDataFile << "LEFT" << lmsg->header.seq << " " << std::setprecision(9) << std::fixed << (lmsg->header.stamp.sec + lmsg->header.stamp.nsec/1e9) << std::endl;

    // output diagnostic information
    std::cout << "Wrote left image " << lmsg->header.seq << " to file." << std::endl;
  }
  // if the message was not properly decoded into an image matrix, output
  // diagnostic information
  catch (cv_bridge::Exception& e)
  {
    ROS_ERROR("Could not convert from '%s' to 'bgr8'.", lmsg->encoding.c_str());
  }
}

// a callback function which is executed whenever a new message is received on
// the subscribed topic "NEST_ZED/right_image". This function decodes the image
// from the message and records it to a file. The image time stamp is recorded
// to the time stamp data log file.
void rightImageCallback(const sensor_msgs::ImageConstPtr& rmsg)
{
  try
  {
    // decode the image from the message
    cv::Mat right_rect = cv_bridge::toCvShare(rmsg, "bgr8")->image;
    cv::waitKey(1);

    // create a unique file name for this image and write the image to a file
    std::string filename = "/home/nestuser/Rectified_Image_Log/R" + std::to_string(rmsg->header.seq) + ".ppm";
    cv::imwrite(filename,right_rect);

    // parse the image time stamp from the message and write it to the time
    // stamp data log file
    ImageDataFile << "RIGHT" << rmsg->header.seq << " " << std::setprecision(9) << std::fixed << (rmsg->header.stamp.sec + rmsg->header.stamp.nsec/1e9) << std::endl;

    // output diagnostic information
    std::cout << "Wrote right image " << rmsg->header.seq << " to file." << std::endl;
  }
  // if the message was not properly decoded into an image matrix, output
  // diagnostic information
  catch (cv_bridge::Exception& e)
  {
    ROS_ERROR("Could not convert from '%s' to 'bgr8'.", rmsg->encoding.c_str());
  }
}

// a callback function which is executed whenever a new message is received on
// the subscribed topic "NEST_ZED/stereo_image". This function decodes the image
// from the message, splits the stereo image into its left and right image
// components, and records the left and right images to files. The image time
// stamp is recorded to the time stamp data log file.
void stereoImageCallback(const sensor_msgs::ImageConstPtr& smsg)
{
  try
  {
    // decode the image from the message
    cv::Mat stereo_rect = cv_bridge::toCvShare(smsg, "bgr8")->image;
    cv::waitKey(1);
```

```

    // separate the stereo image into its left and right images
    cv::Mat left_rect(stereo_rect.rows, (stereo_rect.cols/2), CV_8UC3);
    cv::Mat right_rect(stereo_rect.rows, (stereo_rect.cols/2), CV_8UC3);
    cv::Mat tempLeft = stereo_rect(cv::Range(0,left_rect.rows), cv::Range(0,left_rect.cols));
    cv::Mat tempRight = stereo_rect(cv::Range(0,right_rect.rows), cv::Range(left_rect.cols,left_rect.cols+right_rect.cols));
    tempLeft.copyTo(left_rect);
    tempRight.copyTo(right_rect);

    // create unique file names for the images and write the images to files
    std::string leftfilename = "/home/nestuser/Rectified_Image_Log/L" + std::to_string(smsg->header.seq) + ".ppm";
    std::string rightfilename = "/home/nestuser/Rectified_Image_Log/R" + std::to_string(smsg->header.seq) + ".ppm";
    cv::imwrite(leftfilename,left_rect);
    cv::imwrite(rightfilename,right_rect);

    // parse the image time stamp from the message and write it to the time
    // stamp data log file
    ImageDataFile << "STEREO" << smsg->header.seq << " " << std::setprecision(9) << std::fixed << (smsg->header.stamp.sec + smsg->header.stamp.nsec/1e9) << std::endl;

    // output diagnostic information
    std::cout << "Wrote stereo image " << smsg->header.seq << " to file." << std::endl;
  }
  // if the message was not properly decoded into an image matrix, output
  // diagnostic information
  catch (cv_bridge::Exception& e)
  {
    ROS_ERROR("Could not convert from '%s' to 'bgr8'.", smsg->encoding.c_str());
  }
}

int main(int argc, char **argv)
{
  // initialize ROS and define a unique name for this node
  ros::init(argc, argv, "zed_logger");

  // create a handle to this ROS node
  ros::NodeHandle nh;

  // define new ROS subscribers to inform the master ROS node that this node
  // will be receiving messages on the topics "NEST_ZED/left_image",
  // "NEST_ZED/right_image", and "NEST_ZED/stereo_image" with 15 image input
  // buffers. Register the callback functions "leftImageCallback",
  // "rightImageCallback", and "stereoImageCallback" to execute when a new
  // message is received on the respective topic
  image_transport::ImageTransport it(nh);
  image_transport::Subscriber leftSub = it.subscribe("NEST_ZED/left_image", 15, leftImageCallback);
  image_transport::Subscriber rightSub = it.subscribe("NEST_ZED/right_image", 15, rightImageCallback);
  image_transport::Subscriber stereoSub = it.subscribe("NEST_ZED/stereo_image", 15, stereoImageCallback);

  // put this node into a spin state until the node is shutdown, forever
  // looping and continuously pumping callbacks when messages are received
  ros::spin();

```

```
    // close the data log file
    ImageDataFile.close();

    // end of program
     return 0;
  }

```