Hardware Modeling and Machining for UAV-Based Wideband Radar

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Abstract

The Center for Remote Sensing of Ice Sheets (CReSIS) at the University of Kansas is currently implementing wideband radar systems and other sensors that can obtain ice profiling data from Polar Regions using airborne platforms. In particular a 180-220 MHz radar is being developed to operate on the Unmanned Aerial Vehicle (UAV). The UAV has been given the name “Meridian.” The radar system is constrained to be accommodated in a volume of 20in. x 20in. x 10in. with a weight limit of 55kg. In order to optimize the usage of the space, it is critical to use computer aided design CAD tools to perform accurate 3-dimensional modeling of the radar system. This paper presents different models developed in AutoCAD Inventor which allow visualizing all space aspects of the design, while reducing the design cycle. The parts presented here correspond mainly to the digital sub-system of the radar. Full drawings are provided along with a description of the system components modeled.

1. Introduction

The Center for Remote Sensing of Ice Sheets (CReSIS) at the University of Kansas (KU) is currently implementing wideband radar systems and many more devices to measure the surface elevation and thickness of ice sheets in Polar Regions. A case of interest is for developing a radio sounder designed to operate on an Unmanned Aerial Vehicle (UAV). The main purpose of an UAV is to fly over wide masses of land such as Antarctica and Greenland to collect ice profiling data on the ice sheets covering the region. In contrast with other airborne platforms, UAVs can fly over dangerous locations with high flight track repeatability and lower consequences of loss.

As will be discussed later, the Meridian UAV has a limited payload capacity. Therefore, the payload space has to be managed carefully to achieve an optimum volume distribution. We are using 3-dimensional (3D) modeling to visualize complex geometrical inter-relationships between system components. In particular, Autodesk Inventor version 11 was used to create all the computer models. The Inventor model is an accurate 3D digital prototype that enables users to validate design and engineering data as they work, minimize the need for physical prototypes, and reduce costly engineering changes discovered after the design is sent to manufacturing.

The paper is organized as follows: Section 2 presents an overview of the state of the art in regards to the development of UAV platforms. Section 3 presents a description of the KU UAV. Section 4 presents a description of the work that was done and Section 5 presents the conclusion.

2. Overview of the state of the art.

Unmanned aerial vehicles are aircrafts that are able operate without an onboard pilot. Instead, the UAV is either self-piloted or remotely piloted from a distance. UAVs can be as big as a commercial plane or be small enough to fit in a backpack. The U. S. Department of defense primarily started using UAVs earlier than the 1950s. The aircrafts were originally used by the military for surveillance purposes. After successful demonstration of these vehicles, scientists envisioned them as a suitable platform to conduct experimental observations. The functionality of UAVs was combined with the excellent electrical performance of ultra wideband (UWB) technology and UAVs started being used for more than just military missions. UAVs can carry cameras, sensors, and communication equipment as well as other payloads, which can provide a complete solution for remote field observations.

UAVs are usually classified according to the covered range. The Department of defense uses three classifications: close, short, and endurance. Close range refers to aircrafts flying in range of 50 km or less, short range includes aircrafts flying from 50 to 200 km while endurance aircrafts fly beyond 200 km.

3. Description of the KU UAV

The University of Kansas UAV that will be holding the radar system that was modeled in this paper is the Meridian. The endurance, payload, range, and cost all took effect in the design of the Meridian when it was built. The Meridian has a wingspan of 26.4 ft. and a v-tail wing span of 5.5 ft., which is the tail in the shape of a v. The Meridian weighs 1,085 lbs. on take off, 791 lbs. empty, the payload weighs 165lbs., and the fuel weighs 120lbs. It is powered by the Thielert Centurion 2.0 diesel engine giving the UAV 135hp. The propulsion system selected for the Meridian is an exiting piston/ propeller. The Piccolo II system is an onboard communication system that controls the indicated airspeed control, altitude control, turn rate control, and also the navigation system among other things to keep the aircraft level.

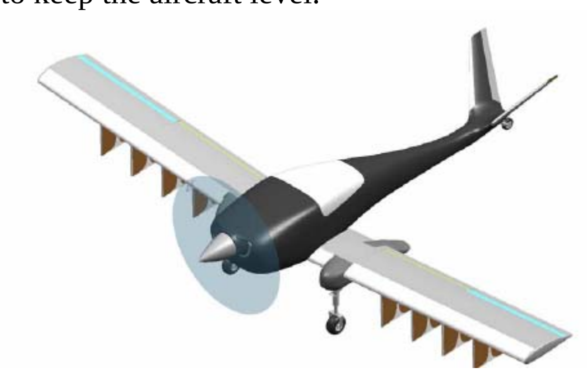

Figure 1
Full view of the Meridian UAV

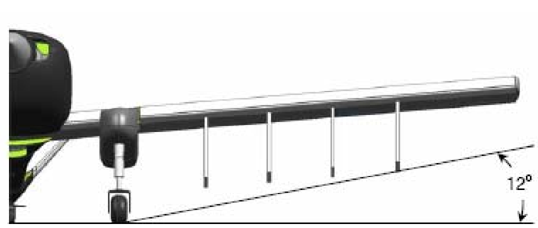

Figure 2
The antennas mounted on the wing

The transmit/receive antennas are mounted on the bottom side of the wings. Each antenna includes a transmitters/receiver module which is the core of the radio-frequency (RF) system of the radar . The T/R modules are all connected to rest of the system which is accommodated in the primary payload bay (Fig. 3). The primary payload bay space is 20 in. by 20 in. and 10 in. in depth.

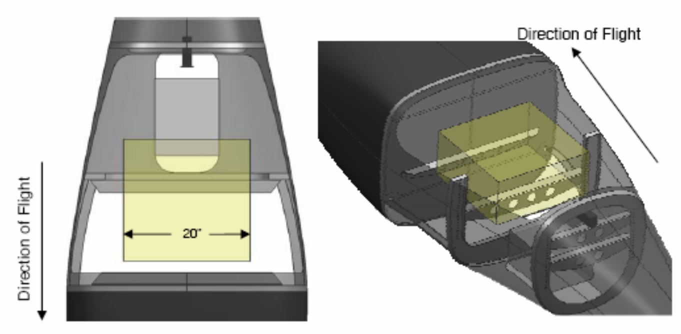

Figure 3
The primary structural space where the radar system will be placed

As mentioned before, UAVs can be classified according to payload and range. Some missions would only need small, portable UAVs that could be controlled from field camps and for some missions large, long range aircrafts that could be operated from remote bases. Because many missions vary, there were three aircraft concepts made for the range and payload which were Tier A, Tier B, and Tier C. The Meridian is capable of being in Tier A or Tier B. Tier A was capable of either carrying the radar depth sounder or the scanning LIDAR topographic mapper, and can travel as much as a 1,000 km. Tier B could easily carry the scanning LIDAR topographic as well as the radar depth sounder and was capable of traveling up to 5,000 km.

CReSIS has developed three different types of aircrafts that could be used for missions. There is the commercially available uncrewed air vehicle, the commercially available piloted aircraft, and the new uncrewed air vehicle design. The major goal for CReSIS is to be able to collect as much data as possible while decreasing operational costs of the aircraft.

4. Description of the work performed

We worked Autodesk Inventor version 11 to create models of the radar sub-systems and the parts therein. The UAV radar instrument is composed of two major sub-systems: the radio frequency (RF) sub-system and the digital sub-system. A block diagram of the radar system is shown in Figure 4.

When the system is in transmission mode, the function of the RF sub-system is to provide the required signal conditioning to the pulse to be transmitted through the antennas. When the system is in receiving mode, the RF sub-system filters and amplifies the signal collected by the antennas.

The digital sub-system is responsible for digitally generate the analog signals that will be transmitted by the RF sub-system as well as digitizing the signals that are collected by the antennas after these signals have been conditioned by the receiver module in the RF sub-system.

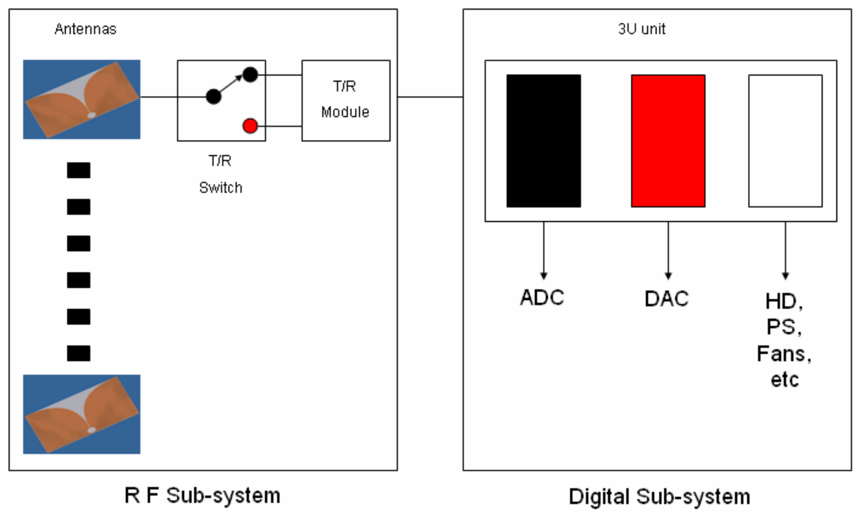

Figure 4
Block Diagram of the UAV Radar System: The RF Sub-system includes the antennas mounted on the wings. The Digital Sub-system is installed in the primary bay

The UAV radar digital sub-system consists of a 3U unit chassis (dimensions 178 mm x 483 mm x 283) which houses the controller, DAC, and ADC cards, hard drives, power supply, and a fan cooling system. We were instructed to create detailed models of these parts from their exact dimensions. The parts were created on the program first to determine how everything would fit together, and estimate how much space would be left if needed to add anything else. This would physically save time when it came to finally putting everything together in the lab. The final goal of this project is to create full and detailed 3-dimensional models of the digital and RF sub-systems of the radar. CAD modeling is quite easy after briefing through the tutorials. The program by Autodesk was very accommodating in making models needed that will help save time when it comes to put together the prototype.

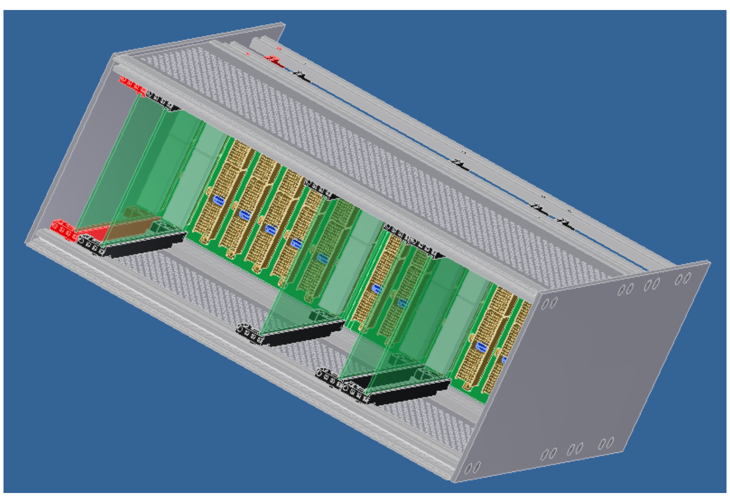

Figure 5
Front view of the 3U unit

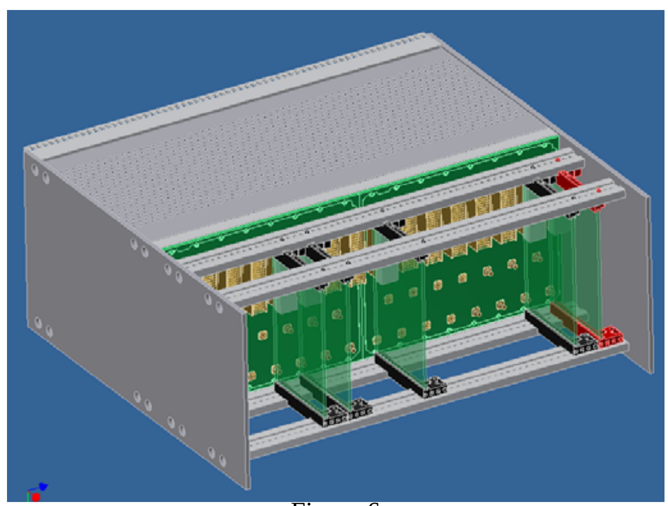

Figure 6
Back view of the 3U unit

Different hard drives were modeled because it was still uncertain which one would be used in the final prototype. Both a 250 gigabyte 3 ½ in. hard drive along with a 60 gigabyte 2 ½ in. hard drive was modeled. Even though it was still undecided which of the two would be used for the project, having both models available will be useful to make the decision. The 2 ½ drive is smaller and can save more space as shown in figure 7 and 8, but can hold as much data as the 3 ½ drive shown in figure 9 and 10. Inventor has tools to make the features on the model realistic in comparison with the actual device. All the mounting holes, connectors and threads were modeled. Calipers which measure by millimeters or inches came into play so the measurement would be accurate to the millimeter. The 3 ½ in. hard drive was later used with the Mini-SAS Backplane which was modeled as well. The two models were used together to come up with a way to quickly be able to put up to four 3 ½ drives in and out simultaneously to save time. A container was molded around the components to create a slot.

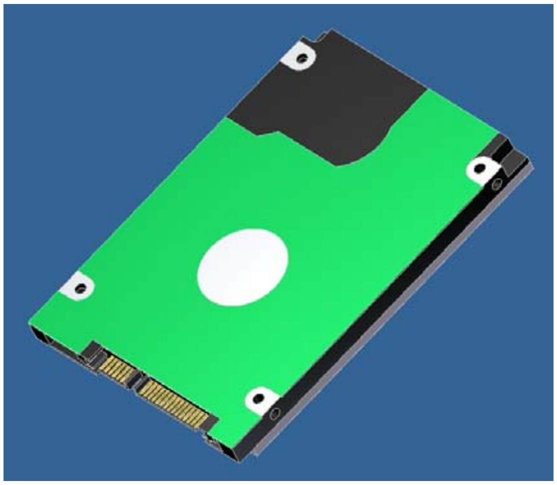

Figure 7
Front view of 2 ½ Hard Drive

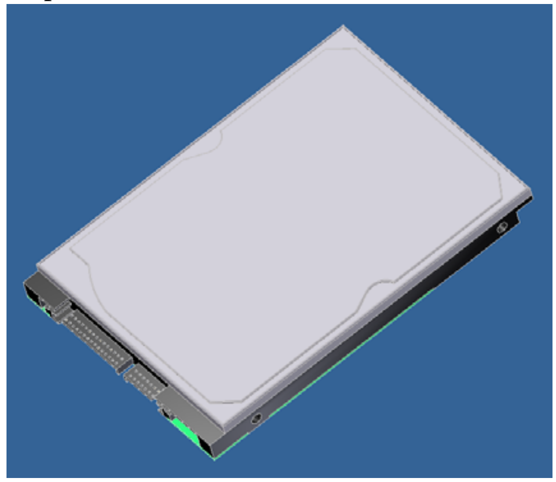

Figure 8
Back view of 2 ½ Hard Drive

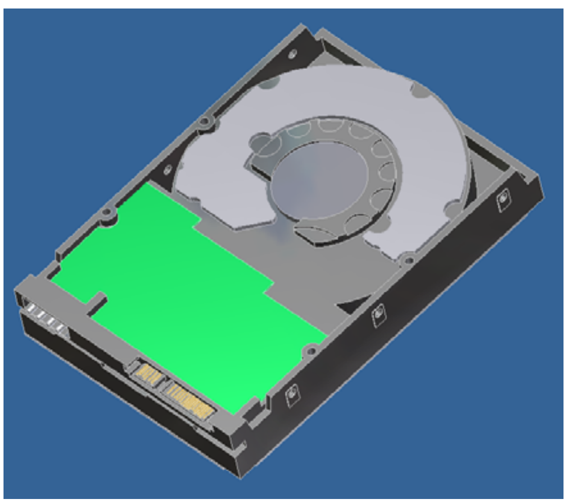

Figure 9
Front view of 3 ½ Hard Dive

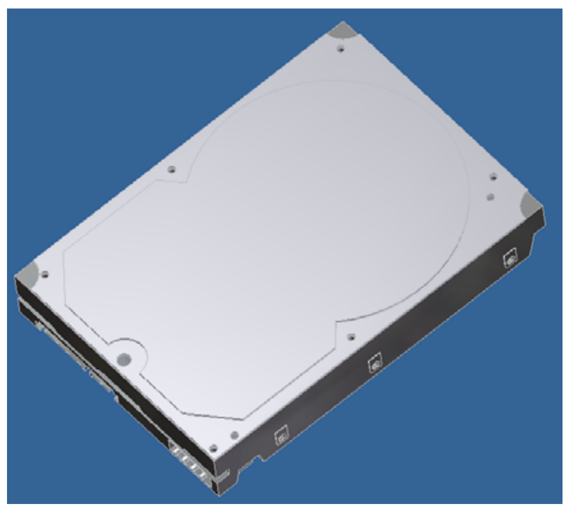

Figure e 10
Back view of 3 ½ Hard Drive

Next the transmitter/receiver antenna which is the Vivaldi-type Antenna was created on the program. The antennas interface to 3U unit by means of the T/R module. The data produced by these blocks is processed and stored digitally in the digital sub-system. The antennas were also modeled to see the maximum area of space to place the transmitter / receiver module. We found that the space available for the transmitter / receiver is about 400 mm by 581 mm and 4.75 mm thick. The transmitter / receiver also had thin copper sheets on both sides that were added into the model.

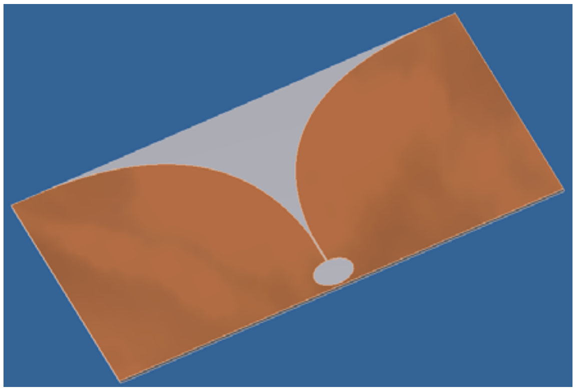

Figure 11
Transmitter/Receiver

An 8 slot CPCI backplane was modeled to fit inside the 3U unit. The 8 slot CPCI backplane was more challenging to make because modeled as a set of sub-assemblies. Later back timing cards along with spacers were made to fit the backplane in the final product.

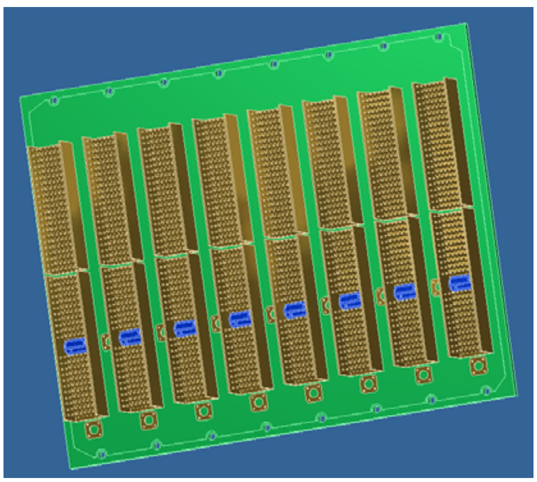

Figure 12
Front view of 8 slot CPCI backplane

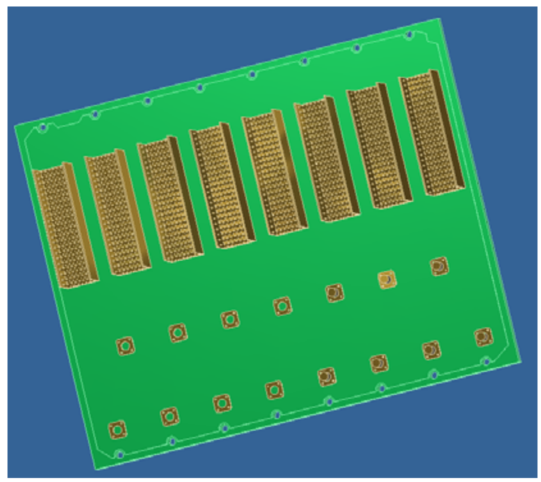

Figure 13
Back view of 8 slot CPCI backplane

Finally, we modeled the power supply subsystem. Many power supply models were considered: Vicor MI ComPAC Military DC DC Switcher. It was undecided which one of the five would be sufficient enough at that present time. The five models that were made are the MC, NC single output series, PC, QC dual output series, and RC triple output series, the biggest of them all. All of the power supplies that were made have a range from 200 – 300 watts and their inputs were 28 VDC. The power subsystem provides battery backup and a disconnect switch to shut down the science payload at their discretion.

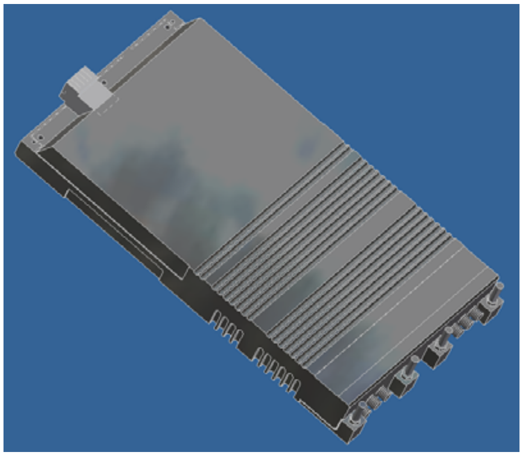

Figure 14
Model of Dual Output PC Series power supply

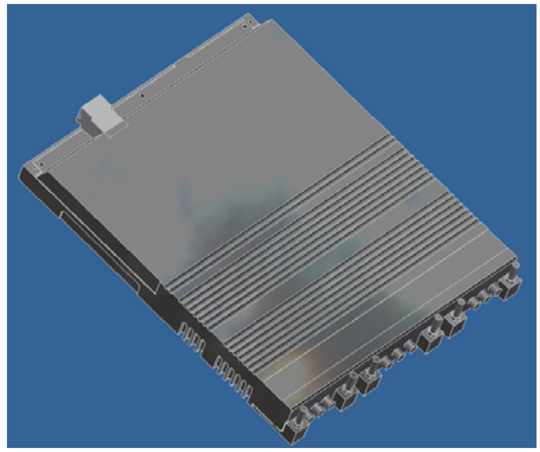

Figure 15
Model of Triple Output RC Series power supply

5. Conclusion

As a result, the models that were made aided in giving a visual design of how the radar system should be organized in the constrained space. Time will be saved in the prototyping cycle because the parts can be moved around on the computer to assist in the design of the final product. Some parts were modeled to improve upon; most parts correspond mainly to the digital sub-system of the radar. After everything was made, the prototyping cycle started. Two 8 slot backplanes were put in the 3U unit. The whole 3U unit was later put in the 20 in. by 20 in. box along with the 2 ½ hard drive tray, power supply, and a custom made fan tray. An EMI shield that was modeled was also incorporated on one of the doors to bring in filtered air to keep everything cool. The final outcome was a complete prototype design of the radar system.

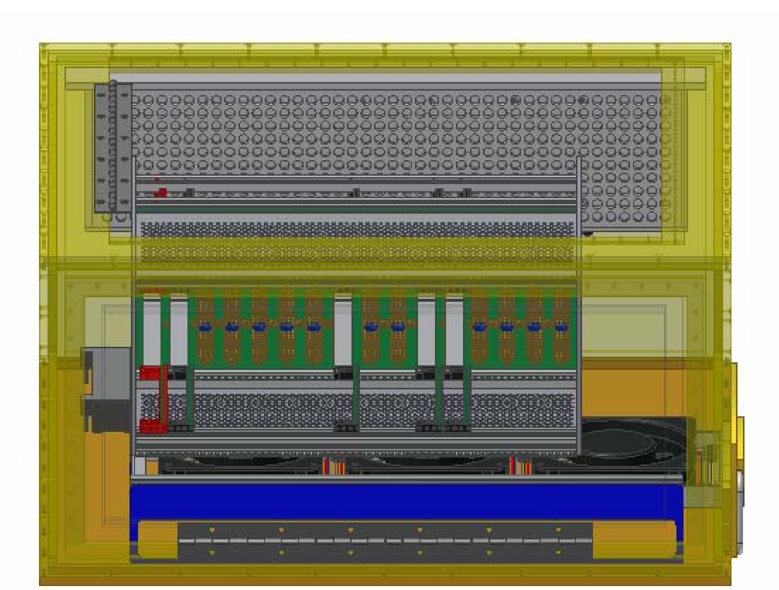

Figure 16
Front view of the Digital Sub-system installed in the primary

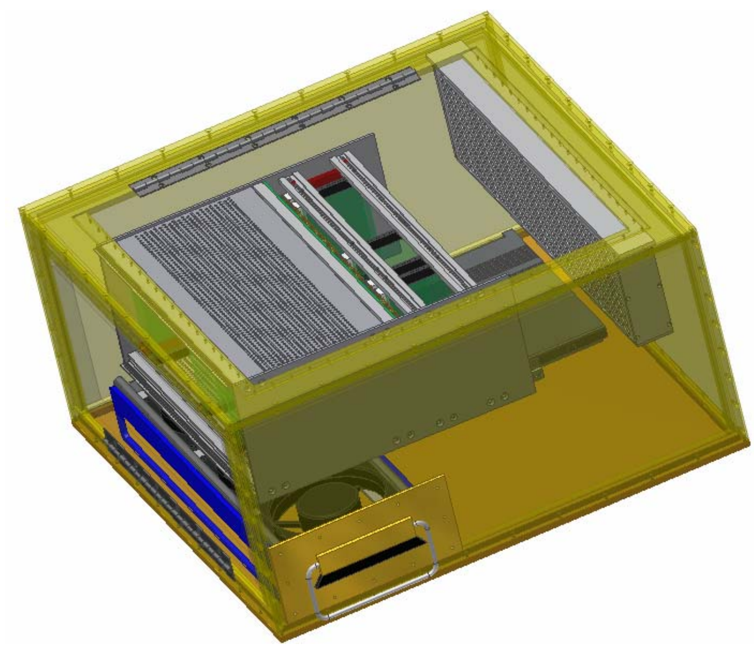

Figure17
Side view of the Digital Sub-system displaying the sliding door for the fan tray

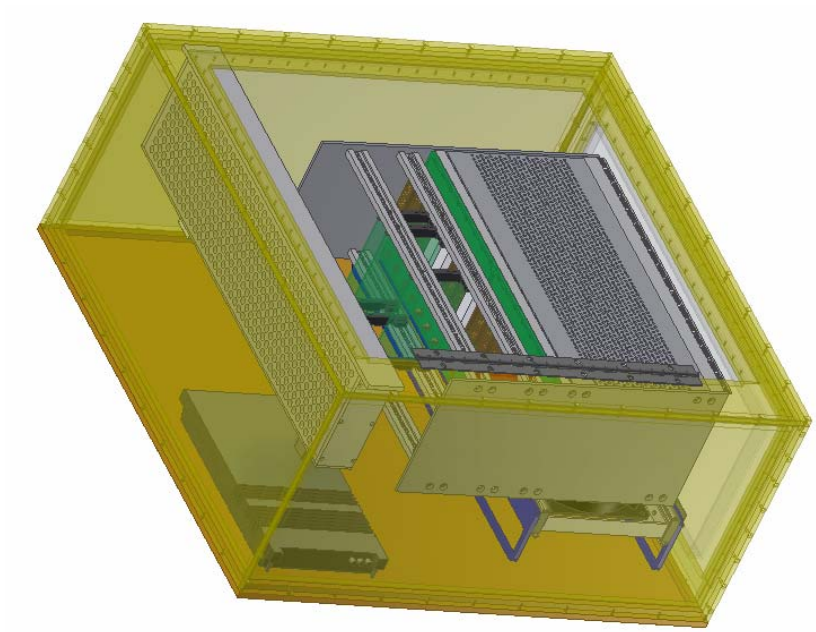

Figure 18
Back view of the Digital Sub-system showing the power supply along with the 2 ½ hard drive tray mounted on the back wall

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