Speaker 1 (00:14):

Hello, my name is Wes Powell. I'm the principal technologist for Avionics within the Space Technology Mission Directorate at NASA. I'll be providing you an overview of our needs for advanced avionics in the near future.

First, a definition of avionics. Avionics is broadly defined as the electronic systems within aircraft and spacecraft. However, this presentation will focus more narrowly on space systems. Here we define avionics as the hardware and software infrastructure necessary for the command and control of spacecraft and surface assets. Thereby providing the onboard intelligence and interconnection to integrate the functions of other subsystems and manage their operation as a whole.

Avionics can be viewed as a foundational technology, providing resources to enable many other functions within space systems. One example of this would be autonomous landing systems that rely on the computing resources provided by avionics. Avionics can in and of itself be viewed as a subsystem, but avionics components are often embedded within other instruments and subsystems as well. Examples of this include Field Programmable Gate Arrays that are embedded within Software Defined Radios and processors and memories embedded within science instruments.

There are some functions that are sometimes defined as being within the scope of avionics, including power systems, communications and navigation. These areas are not addressed here in this presentation, but will be addressed in other presentations.

There are many fundamental technologies that are required to implement avionic systems. I'll mention a few of them here, starting with architectures. There are architectures needed at various levels of abstraction ranging from the system level, which would dictate how boxes and subsystems are interconnected all the way down to architectures within a chip itself.

Computing systems are needed which can include processors of a variety of devices, memory as well as light software. Interconnect is needed, which includes wired, both copper and optical cabling, as well as wireless interfaces, and computer human interfaces are needed which can include audio systems, displays and the graphics hardware needed to drive those displays.

Other areas that are included include packaging, security, sensor, data acquisition and control, as well as things such as cabling and support circuitry.

Here we've provided a couple of illustrations, one for crewed mission avionics and another for robotic science mission avionics. And what you'll see is there are some commonalities between these two, including the presence of computing, onboard networks, data storage, subsystem control, housekeeping sensing, and flight software. Some of the unique aspects of crewed missions include the inclusion of computer human interfaces, greater degrees of redundancy to ensure crew safety, increased complexity.

And one example of which is the Redundant Onboard Network that's shown in the picture may be augmented by one or more wireless systems. And then serviceability as the crew is able to service and maintain the avionics once on orbit. Some specific aspects of robotic science mission avionics include first off a much wider variability in mission sizes, which can range to small mission such as cube sets all the way up to flagship missions, such as the James Web Space Telescope.

With some of these mission sizes, there can be much more tightly constrained size, weight, and power requirements than you would see on crewed missions. You'll also see redundancy tailored to specific mission requirements where some less critical missions may employ just single string avionics, while more critical flagship missions may have fully redundant cross strapped avionic systems.

Science missions may also be deployed to harsher environments, including extreme environments, such as Europa and the surface of Venus. And historically there has been limited serviceability of science mission avionics, although that could change as our robotic servicing technologies increase in the future.

There's some specific challenges that are faced when developing space avionics. These include radiation or Total Ionizing Dose can cause performance degradation and failure, and single event effects can cause data corruption, functional upsets, and permanent failure. Temperature is another challenge. And while most missions maintain avionics operating temperatures between zero and 40 degrees Celsius, temperature extremes for other missions can range from negative 180 degrees Celsius for shadowed lunar surface missions to above 400 degrees Celsius for the surface of Venus.

Mission lifetime is another challenge and this can vary widely again between different missions or some smallsat missions can have planned mission durations of less than a year while crewed missions and flagship science missions can have durations up to 15 years.

Another challenge is the need for resilience. Avionics must provide sufficient resilience to meet mission objectives in the presence of faults. Depending on mission requirements, this resilience can be achieved through operational approaches, for instance, placing the spacecraft in a known safe state when a fault occurs, architectural redundancy such as triple modular redundancy that's illustrated to the right, supervisory circuits such as watchdog timers, and over voltage and current protection circuitry. And another means for achieving resilience is a selection of high reliability components to develop the avionics. Other challenges include planetary protection requirements that may require harsh processing prior to launch and some planetary environments, which are caustic, notably sulfuric acid clouds on the atmosphere of Venus.

So I'll now present the avionics technology gaps that we're tracking. To achieve the outcome of onboard computing, enable autonomous landing, surface navigation, robotic servicing and assembly, data processing for food and science, robotic science missions. We've identified some gaps including general purpose processors, co-processors, memory, point load converters, machine learning devices, as well as high performance, single board computers and software infrastructure.

To provide storage to support nominal and contingency mode operations for crewed missions, we will need advanced onboard mass data storage. For crewed human interfaces, we need displays and controls that can operate and provide situational awareness for missions beyond lower earth orbit, can operate reliably in Cislunar and Mars environments. These include radiation tolerant displays, EVA heads up display optics, graphics processor units, audio systems and mobile computing devices.

In the area of radiation tolerant interconnect, we need onboard networks to enable high bandwidth video and sensor communication for crewed and robotic science missions. And beyond that high bandwidth, we also need to ensure the integrity of mission critical and time critical command and control traffic. For this we're looking for high bandwidth network protocols and physical layer devices, high rate deterministic wireless networks and smart power buses.

We also need sensors to enable crew situational awareness as well as navigation and robotic servicing and assembly for crewed and science missions. Here we're looking for imaging sensors, proximity sensors, and wireless sensor networks.

In the area of extreme environment electronics, we're looking for electronics that can withstand the extreme temperatures of lunar and planetary surfaces, as well as high radiation electronics that can withstand the high radiation environment of some planetary destinations.

We've also identified some push technologies of interest and while these technologies don't have as direct a connection for infusion into upcoming missions, they're nonetheless viewed as being important for the future. Within the area of the advanced computer human interfaces, we're looking to technologies, including speech recognition, virtual reality, and augmented reality to help reduce the size, weight, and power of our electronics. We're looking for advanced packaging, additively manufactured electronics, mixed signal structured ASICs, or reduced size, weight and power of interconnect. We're looking for miniaturized and or reduced mass wiring conductors, connectors, and shielding as well as new technologies, including data over power networks.

To advance the capabilities of future computing systems. We're looking to integrate photonics to contribute to that area. And in the area of security, we're looking for defense in depth software security.

In summary, future crewed and science missions will present new challenges. These range from increased autonomy to increased sensor data rates, harsh environments, increased volume of data to manage, and long duration missions. We're going to need advanced avionics technologies to meet all of these needs. Thank you for your time.