Space Plug-and-Play Avionics

Space plug-and-play (PnP) avionics (SPA) is an engineering approach to make complex systems seem simple. Most take for granted that when plugging a keyboard into a computer it will simply work, but it took the personal computing industry many years to make this true. Now, the technology can be similarly applied to aerospace systems. SPA combines sophisticated hardware and software concepts to make plug-and-play possible. SPA-based systems help in their own construction, integrating in a fraction of the time normally required. SPA involves several key concepts:

• ***Self-description:*** Components describe themselves using an abstraction referred to as the eXtended Transducer Electronic Datasheet (xTEDS) replacing in some cases the need for accompanying documentation. Even individual software modules can carry their own xTEDS, blurring the boundaries between hardware and software.

• **"*Machine-negotiated interfaces*":** SPA components automate a concept referred to as "discovery and join," in which components are automatically recognized when plugged into a system and networked with other components, both hardware and software.

• ***Appliqué Sensor Interface Module (ASIM):*** To make it easier to develop SPA components, AFRL created the ASIM, which can act as a bridge between legacy devices and the "plug-and-play universe." ASIMs already understand SPA, contain electronic datasheets and are flexible enough to support a wide variety of spacecraft components. They are not always needed, particularly in new designs that can implement SPA concepts directly.

• ***Satellite Data Model (SDM)*:** SDM is the software the binds together the other pieces of the SPA approach. It acts as a broker, finding the pieces as they are added to a system and linking them with other parts of the SPA network that need them. It has been called at times "side-ware," a type of software that facilitates the operation of SPA networks without getting in the way. This makes SDM different from other brokering architectures, such as Common Object Request Broker Architecture, or CORBA.

• ***Test bypass*:** SPA employs a novel approach to permit almost any component to be tested in system, institutionalizing a concept sometimes called "hardware-in-the-loop." With test bypass, dozens of components can be tested by synthetically supplying cues of heat, motion and other phenomena, in effect, providing an illusion to the system that it is "flying" while still on the ground.

• ***Push-button Toolflow (PBTF):*** Possibly the most ambitious concept within the SPA approach is the idea of using web-based software tools to translate a user's ideas directly into a buildable spacecraft. AFRL hopes someday to establish the ability for small groups to define and deploy systems using powerful wizard-driven dialogs that are themselves extensible by others who develop spacecraft components and systems.

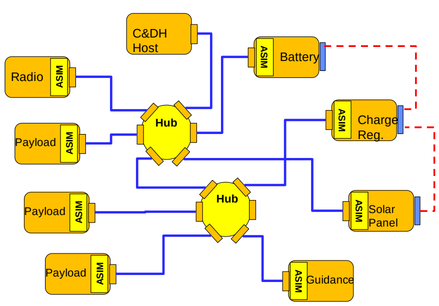
Influenced by decades of work in space electronics, the formal development of SPA began in 2004. Since then, nearly a dozen workshops have been held, standards have been drafted, and a number of implementations have been developed in the laboratory and flown in sub-orbital and orbiting spacecraft demonstrations. Hundreds of ASIMs have been developed in support of this work, and SPA has been implemented in a variety of system forms, ranging from coffee-cup sized CubeSats to 400 kg. (882 lbs.) tactical spacecraft.

SPA will benefit the warfighter by reducing the time required to build spacecraft from months and years to days and weeks. These ideas are sometimes called "responsive space," in which spacecraft can be rapidly developed in response to urgent needs. The same concepts used to build systems more quickly can benefit a wide range of other systems that seek to exploit new technological developments more quickly. Just as a new keyboard or mouse can be quickly added to an existing computer, with SPA, an improved payload, radio, gyro or other component could be rapidly swapped in an existing system. SPA is of benefit to those who simply wish to reduce the complexity in system developments that give rise to cost and schedule overruns.

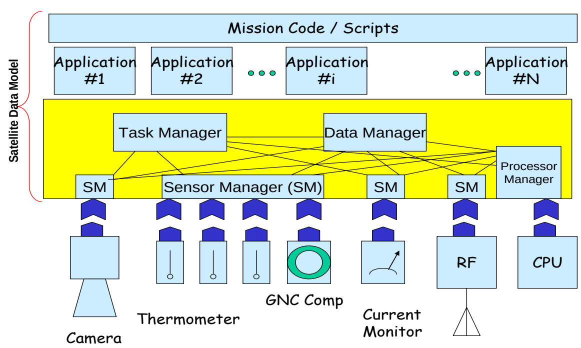
The concepts of SPA, through technology, may finally realize the dream of interoperability and interchangeability that has remained a hope for decades in the Department of Defense.

The work of SPA continues, even as a growing body of research has been developed and reduced to practice, through AFRL's Responsive Space Testbed supporting in-house and contract activities. Much of the SPA products (documentation, reports, standards, intellectual property, software) are available publically or to qualified recipients for further use and exploration. Courses based on these ideas have been developed, along with kits, that demonstrate the key principles and provide researchers "hands-on" exposure to SPA.

SPA Concepts and Facilities



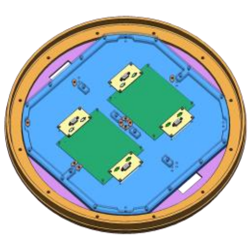
SPA networks - Components are plug-and-play objects that can be freely interconnected through hubs or routers that automatically distribute power, data and synchronization signals.



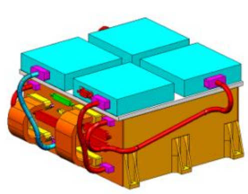
SPA software - The satellite data model handles the internal organization of data in the SPA approach. Electronic datasheets in hardware and software are used to cue the self-organization of systems.

Responsive Space Testbed - Serves as both a technology incubator and integration resource where concepts are created and SPA systems demonstrated.

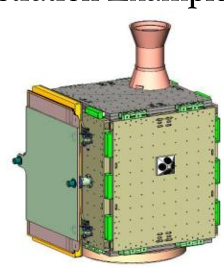
SPA Demonstration Examples



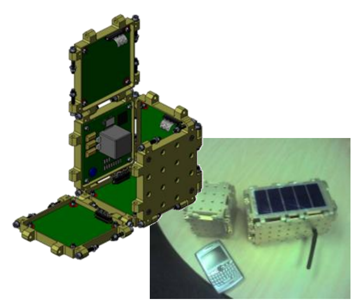
Re-entry Space Experiment - A sounding rocket test that implemented a four-port sub-orbital SPA-U demonstration at White Sands Missile Range.



Spacecraft Avionics Experiment - A four-port SPA-U experimental payload integrating a number of backup components as part of the TacSat 3 space mission.



Plug-and-play Satellite - A 48-port SPA-S system, in which every major component, even the structural panels, were built as plug-and-play components.



CubeFlow - A miniaturized SPA-U based modular system designed to be compliant with the popular CubeSat standard. Used to support simple space experiments and outreach.

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