

Space Plug-and-Play Architecture (SPA) Standard

System Capabilities

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Abstract

The SPA System Capabilities Standard defines the principles upon which the architecture is based, the services that a SPA system provides, and the capabilities that are required of a SPA system. Each requirement in the Capabilities document is mapped to the other SPA standards where they are discussed in detail.

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Foreword

This standard was developed through a partnership of the Air Force Research Laboratory Space Vehicles Directorate, the Air Force Office of Operationally Responsive Space, numerous government contractor teams, independent contractor teams, and academic experts. The Space Plug-and-Play Architecture is a collection of standards developed to facilitate rapid constitution of spacecraft systems using modular components. This document enumerates the principles upon which the SPA approach is based, the services provided by a SPA system, and the requirements for SPA system capabilities.

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Introduction

SPA is a collection of standards designed to facilitate rapid constitution and testing of spacecraft systems using modular components. The SPA concept was initiated by the Air Force Research Laboratory (AFRL) Space Vehicle Directorate in 2005. Since that time the approach has been investigated through collaboration with the Air Force Office of Operationally Responsive Space (ORS) and numerous industry partners. The concept has been demonstrated through both ground-based and flight experiments.

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1 Scope

This document defines what constitutes a SPA system by outlining the basic principles of the architecture and the services that a SPA system provides. The capabilities defined herein flow-down to the individual SPA Standards documents.

2 Tailoring

When viewed from the perspective of a specific program or project context, the requirements defined in this Standard may be tailored to match the actual requirements of the particular program or project. Tailoring of requirements shall be undertaken in consultation with the procuring authority where applicable.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some exceptional cases, modification and addition of requirements in the standards.

3 Applicable Documents

The following documents contain provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

AIAA G-133-1-201X *SPA Guidebook*

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

AIAA	American Institute of Aeronautics and Astronautics
PPS	Pulse-per-Second
QoS	Quality of Service
SPA	Space Plug-and-Play Architecture
SSI	SPA Services Infrastructure
UUID	Universally Unique ID
xTEDS	Extensible Transducer Electronic Data Sheet

4.2 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

ASIM

An ASIM is a small chip that may be incorporated in a device to allow the device to communicate using standard SPA messaging protocols. The ASIM is programmed with information about the device and its functions. This is similar to the idea of using a USB chip to make components compatible with USB standards.

NOTE Devices may be made compliant with SPA protocols and standards without the use of an ASIM by designing the device to function according to the SPA messaging and ontology standards. ASIMs are available to make legacy components compatible with SPA systems.

SPA Component

A SPA compliant hardware or software component

SPA Application

A software SPA component

SPA Device

A hardware SPA component

SPA Compliant

Adheres to applicable SPA standards

SPA Core Component

A SPA component which provides one or more SPA service

SPA Gateway

A uniquely addressable SPA core component used to bridge between two different SPA network spaces

SPA Network

An addressable and routable physically connected infrastructure composed of standard SPA transports for the purpose of transporting SPA messages between SPA endpoints and SPA gateways. The SPA network is made available as a SPA service to SPA components through a standard interface.

SPA Processor Resource

A SPA device containing a processor that advertises itself via xTEDS as a discoverable, shared resource for executing SPA applications.

SPA Services

SPA-specific capabilities and functionality available to SPA components by SPA core components through a standard interface.

SPA System

An integrated collection of interoperating SPA components

SSI

The SPA Services Infrastructure (SSI) consists all SPA core components that provide SPA services to the system.

Time Latency

The time lapse between issuance of the PPS timing signal and receipt by each subscribing component or endpoint

xTEDS

An electronic data sheet used as the SPA component interface specification

5 SPA Systems

The Space Plug-and-Play Architecture (SPA) is centered on the idea that components for any networked system can be added to the network and will have the ability to communicate with the system without separately installing drivers, software interfaces, or other interface mechanisms. In order to distinguish the SPA concept from other “plug-and-play” approaches the principles of a SPA system and the services provided by that system are outlined below.

5.1 SPA Principles

The following principles bound the SPA system and differentiate this approach from other plug-and-play systems.

- a) SPA components shall only communicate through standard messages.
- b) SPA components shall conform to an approved SPA-x interface (-U, -S, -1, -O, etc.) such that they operate without modification when integrated with a compatible SPA-x infrastructure.
- c) Components shall be self-describing with sufficient detail for the purpose of correctly matching SPA components in roles of producers and consumers of data and services (IAW an approved xTEDS schema and Common Data Dictionary).
- d) SPA data producers and consumer needs are matched through a standard query service.
- e) SPA networks are topology agnostic and self-organizing.
- f) A SPA Device shall be physically mountable on a compliant SPA structure according to one of the applicable SPA mechanical standards.

5.2 SPA Services

All SPA systems provide the following services that meet the requirements of the SPA Principles.

Command/response messages – SPA components send command messages to initiate an action, and send response messages to respond to command messages. A SPA component's xTEDS details the command and response messages supported by the component.

Component detection – A SPA system automatically detects hardware or software components that are added to the system.

Component detects dependency failure – SPA components detect or are notified when a component that they are subscribed to is unable to provide the data requested.

Components provide ICD – SPA components provide information about their functions and use to the system. This may be done directly or the device may provide a pointer to information stored elsewhere but the device must enable the system to learn of its capabilities without external manipulation.

Components register – SPA components register with the network, informing the system as to the data the component produces, the operational modes that it has available (if applicable), and the data that it will consume.

Publish/subscribe messages – SPA components publish data through messages. SPA components can subscribe to data messages as needed.

Standard mechanical and electrical interfaces – SPA systems provide standard mechanical and electrical interfaces for SPA devices.

Standard 28V power interface – SPA systems provide standard 28V power interface for all SPA devices.

System monitors component status - A SPA system monitors component status (fully operational, dependency failures, component failure, etc.).

System provides common time to component – A SPA system must provide common time to the system components.

6 Capability Requirements

The capability requirements defined in this document are numbered. Annex A shows the mapping of each numbered requirement to the SPA standard document that addresses that requirement.

6.1 General Capability

(SPA001) SPA devices shall be designed to reject internal heat through conduction to their mounting surface or radiation to the surroundings.

(SPA002) System configuration data required by a SPA component shall be available from a configuration source within the SPA system.

6.2 Standards-Based Interface Capability

(SPA003) A SPA component interface shall be described to a requesting SPA component by an xTEDS which conforms to the SPA Ontology Standard.

(SPA004) SPA components shall utilize SPA standard messages that are independent of programming languages to access SPA services in accordance with the SPA Interface Standard.

(SPA005) SPA devices shall comply with a standardized mounting interface which is designed to withstand the loads associated with launch, ascent and on-orbit operations.

(SPA006) The SPA mounting interface standard shall allow SPA devices to be placed at multiple locations on the spacecraft structure to provide flexibility in spacecraft configurations.

(SPA007) SPA devices shall provide a SPA compliant connector as specified in the SPA Physical Interface Standard.

6.3 Component "Plug" Capability

(SPA008) The SPA system shall provide the ability to register a new SPA component during spacecraft operations without a priori knowledge of their physical or network location.

(SPA009) The SPA system shall provide the ability to re-register a previously registered SPA component that has been updated.

(SPA010) The SPA system shall provide the ability to unregister a previously registered SPA component.

(SPA011) Each SPA component within a SPA system shall be identified with a universally unique identifier (UUID) in accordance with the SPA Interface Standard.

(SPA012) A SPA component shall provide an xTEDS to register in the SPA system.

6.4 Component "Play" Capability

(SPA013) A SPA component shall become discoverable within the SPA system when it registers and is uniquely addressable by other SPA components.

(SPA014) The SPA system shall make no distinction (in a data sense) between SPA devices and applications.

(SPA015) A SPA component's xTEDS shall be made available during discovery to a requesting SPA component in response to the requester's use of a query message.

(SPA016) The SPA system shall provide the ability to discover SPA components during spacecraft operations without a priori knowledge of their physical or network location.

(SPA017) The SPA system shall provide the ability for a SPA component to utilize another SPA component during spacecraft operations without a priori knowledge of their physical or network location.

6.5 Network Capability

(SPA018) The SPA system shall not require external data sources to operate.

(SPA019) SPA components shall be usable at any location on the network with a matching subnet protocol.

(SPA020) SPA gateways shall be used to negotiate between heterogeneous SPA standard transport networks.

(SPA021) The SPA system shall provide the ability to route SPA messages on a variety of SPA standard transports.

(SPA022) Configuration of the SPA network shall be implemented as an automated system-wide protocol without tailoring for the specific application.

(SPA023) The SPA system shall support QoS mechanisms in accordance with the SPA Network Standard.

(SPA024) The SPA system shall support SPA message packet integrity checking in accordance with the SPA Interface Standard.

(SPA025) The SPA system shall route messages between SPA components across the SPA network.

6.6 Common Time Capability

(SPA026) The SPA system shall be capable of providing the current synchronized system time.

(SPA027) SPA devices shall be capable of handling the receipt of a timestamp and sync signal distributed on all supported subnet varieties as defined by SPA.

(SPA028) The SPA system shall be capable of arbitrating the master clock source.

6.7 Fault Tolerance Capability

(SPA029) A SPA core component shall be able to detect an internal fault condition.

(SPA030) A SPA core component shall attempt fault recovery upon detection of an interface fault condition.

(SPA031) A SPA core component shall attempt fault reporting upon detection of an internal fault condition.

(SPA032) The SPA system shall provide for the self-healing of a failed network route by dynamically determining and providing transparent adaptation to alternate networking routes if alternate routes are available.

(SPA033) A SPA component shall detect a dependency failure.

(SPA034) A SPA component shall respond with operational status when requested.

(SPA035) The SPA system shall monitor the operational status of all SPA components.

(SPA036) The SPA system shall provide notification of the operational status of all SPA components.

6.8 Security Capability

The SPA standards do not address system security. Any system-level security issues that arise out of the SPA design approach that are specifically inherent to SPA may be addressed in the future.

6.9 Power Capability

(SPA037) SPA devices shall be designed to operate over a specified voltage range and maximum current draw.

(SPA038) SPA devices shall withstand specified over-voltage, under-voltage, transient and ripple conditions without permanent damage or degradation.

(SPA039) SPA devices shall comply with primary power, secondary power and digital grounds in the overall spacecraft grounding requirement.

(SPA040) The SPA system shall provide power at the specified voltages, to connected SPA components.

6.10 Test Support Capability

(SPA041) The SPA system shall support a mechanism to allow SPA device data interfaces to be manipulated for the purposes of rapid testing.

Annex A SPA Requirements Mapping (Informative)

Table 1 shows how each of the requirements in the SPA System Capabilities Standard flow down to the other SPA standards. The referenced document contains specific information on meeting each of the requirements.

Table A.1 – SPA System Capability Requirements Flow-down

Requirement	Logical Interface Standard	Network Standard	Ontology Standard	Power Standard	System Timing Standard	Physical Interface Standard	SSI
SPA001						X	
SPA002	X		X				X
SPA003			X				
SPA004	X						X
SPA005						X	
SPA006						X	
SPA007						X	
SPA008	X						X
SPA009	X						X
SPA010	X						X
SPA011	X						
SPA012	X						
SPA013		X					
SPA014			X				
SPA015	X						
SPA016	X						X
SPA017	X						X
SPA018		X					X
SPA019		X					

Requirement	Logical Interface Standard	Network Standard	Ontology Standard	Power Standard	System Timing Standard	Physical Interface Standard	SSI
SPA020		X					
SPA021		X					X
SPA022		X					X
SPA023		X					X
SPA024		X					X
SPA025		X					X
SPA026					X		
SPA027	X				X		
SPA028					X		X
SPA029							X
SPA030							X
SPA031							X
SPA032		X					X
SPA033							X
SPA034							X
SPA035							X
SPA036							X
SPA037				X			
SPA038				X			
SPA039				X			
SPA040				X			X
SPA041	X						X