

Space Plug-and-Play Architecture Standards Development Guidebook

AIAA standards are copyrighted by the American Institute of Aeronautics and Astronautics (AIAA), 1801 Alexander Bell Drive, Reston, VA 20191-4344 USA. All rights reserved.

AIAA grants you a license as follows: The right to download an electronic file of this AIAA standard for storage on one computer for purposes of viewing, and/or printing one copy of the AIAA standard for individual use. Neither the electronic file nor the hard copy print may be reproduced in any way. In addition, the electronic file may not be distributed elsewhere over computer networks or otherwise. The hard copy print may only be distributed to other employees for their internal use within your organization.

Space Plug-and-Play Architecture Standards Development Guidebook

Sponsored by

American Institute of Aeronautics and Astronautics

Approved November 2012

Abstract

This document provides a guideline for spacecraft platform, subsystem, and component (including payload) developers for integrating plug-and-play characteristics into spacecraft structures, avionics, and hardware and software components to promote their rapid integration. This guideline will be used as the foundation for Space Plug-and-play Architecture (SPA) standards. The SPA community anticipates adding protocols (e.g., Ethernet as SPA-E) as the PnP capabilities are normalized.

Published by
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Reston, VA 20191

Copyright © 2013 American Institute of Aeronautics and
Astronautics
All rights reserved

No part of this publication may be reproduced in any form, in an electronic retrieval system
or otherwise, without prior written permission of the publisher.

Printed in the United States of America

ISBN 978-1-62410-229-5

Contents

Foreword..... v

Introduction vii

1 Scope..... 1

2 Tailoring..... 1

3 Applicable Documents 1

3.1 Normative References 1

4 Vocabulary..... 1

4.1 Acronyms and Abbreviated Terms..... 1

4.2 Terms and Definitions 3

5 Architecture..... 5

5.1 SPA Inside a General Space Architecture 5

5.2 SPA Inside 5

6 SPA Goals, Concepts, Principles, and Structure 7

6.1 Primary SPA Goal: Eliminating Barriers to Rapid Satellite Deployment 7

6.2 SPA Core Concept and Essential Services 7

6.3 SPA Basic Capabilities 9

7 SPA Implementation 10

7.1 Overview..... 10

7.2 Spacecraft Software Services From SPA 11

7.3 SPA Networking..... 12

7.4 SPA Components (Devices and Applications)..... 14

8 Example SPA Implementation 16

8.1 Turning on a SPA System: What Happens When..... 16

8.2 Panel Concept..... 20

9 SPA Tools..... 21

9.1 Design Tools..... 21

9.2 Test Tools..... 24

10 Summary of SPA Standards 27

10.1 General SPA Standards..... 27

10.2 Specific Application-Specific Standards 31

Annex A Reference Architectures and Models 33

A.1 The Data-Centric Plug-and-Play Approach..... 33

A.2 CCSDS SOIS Model..... 35

Figures

Figure 1 – Spacecraft bus architecture (systems view) with SPA overlay..... 6

Figure 2 – SPA core concepts.....	7
Figure 3 – The SPA Logical Model.....	9
Figure 4 – The SPA Services Manager.....	12
Figure 5 – A SPA standard has been defined for each of the SPA system interfaces	13
Figure 6 – The ASIM interfaces the device to the SPA-X network.....	15
Figure 7 – SPA network phases of operation.....	16
Figure 8 – The component discovery sequence	17
Figure 9 – Device registration sequence.....	17
Figure 10 – Message sequence to identify the Component Addressing Service	18
Figure 11 – Messaging sequence for assignment of logical address blocks.....	19
Figure 12 – A structural panel concept.....	20
Figure 13 – SPA port number format	22
Figure 14 – The Test Bypass Interface Network	24
Figure 15 – Test-bypass is implemented with a dual ported register file.....	26
Figure 16 – The Flight Software-in-the-Loop typical configuration using two PCs.....	27
Figure 17 – Component Data Capabilities and Component Network Capabilities.....	28
Figure 18 – The SPA spacecraft single-point grounding approach.....	30
Figure A.1 – SPA/OSI Layer Model correspondence.....	33
Figure A.2 – An OSI/SPA mapping	35
Figure A.3 – SPA graphic.....	36
Figure A.4 – SOIS path between application and device protocol stacks	37
Figure A.5 – Protocol stacks for SPA application on the left; SPA ASIMs on the right.....	37
Tables	
Table 1 – Letter code as it corresponds to the document	22
Table 2 – Letter code for bus voltage	23
Table 3 – Letter code for mechanical and thermal devices.....	23
Table 4 – Letter code for connectors and cabling.....	23
Table 5 – Letter code for test bypass interfaces.....	24

Foreword

The desire to quickly and reliably assemble spacecraft has been a challenge since the 1960s. In the 1990s the international computer market noted a similar need to quickly and reliably assemble computers and computer accessories. The invention of Plug-and-Play (PnP) capabilities is now assumed for any modern terrestrial computer system. PnP capability is defined in various publicly available technical standards.

It is the purpose of the AIAA to capture, in this Space Plug-and-Play Architecture (SPA) Guidebook and associated technical standards, technical approaches to adapt the various computer PnP capabilities to small spacecraft and the space environment.

This Guidebook provides a general description of a data centric spacecraft model used to form the on-board PnP network. Various views are used to clearly indicate how this works. A common ontology is described to allow for a profile specific Common Data Dictionary (CDD) so that a stable set of terms may exist. Interfaces between devices are described to simplify the implementation of PnP at the device level. Finally, those PnP protocols identified to date are generally described, as are the adaptations needed for space application.

The detailed requirements for each of these topics are listed in the respective AIAA SPA standards listed below.

- SPA Networking Standard
- SPA Logical Interface Standard
- SPA Physical Interface Standard
- SPA 28V Power Service Standard
- SPA System Timing Standard
- SPA Ontology Standard
- SPA Test Bypass Standard
- SPA SpaceWire Subnet Adaptation Standard
- SPA System Capability Guide

At the time of approval, the members of the AIAA SPA Committee on Standards were:

Fred Slane, Chair	Space Infrastructure Foundation
Jeanette Arrigo	Sierra Nevada Corporation
Scott Carlson	Utah State University
Ken Conner	PnP Innovations
Don Fronterhouse*	PnP Innovations
Rod Green	Design Group
Jane Hansen	HRP Systems
Doug Harris	Operationally Responsive Space Office
Paul Jaffe	Naval Research Laboratory
Stanley Kennedy*	Comtech Aero-Astro

Ronald Kohl	R.J. Kohl & Associates
Bill Kramer	Independent
Ramon Krosley	Independent
Denise Lanza	SAIC
James Lyke	Air Force Research Laboratory
Joseph Marshall	BAE Systems
Gerald Murphy*	Design Group
Gary Rodriguez	sysRand
Steven Schenk	Comtech Aero-Astro
Robert Vick*	SAIC

The above consensus body approved this document in November 2012.

The AIAA Standards Executive Council (VP-Standards, Laura McGinnis, Chairperson) accepted the document for publication in November 2012.

The AIAA Standards Procedures dictate that all approved Standards, Recommended Practices, and Guides are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any AIAA standards publication, and no commitment to conform to or be guided by standards reports. In formulating, revising, and approving standards publications, the committees on standards will not consider patents that may apply to the subject matter. Prospective users of the publications are responsible for protecting themselves against liability for infringement of patents or copyright or both.

*Alternate CoS Participant

Introduction

This Guidebook provides the introduction to the SPA standard set. The SPA effort is a response to the need for reduced design, fabrication, integration, and test schedules (and therefore related engineering costs) for small spacecraft. The primary goal of SPA is to enable completion of all satellite development phases in days instead of months and years.

With the current technical and standards base, it is common to allocate months in a small satellite development schedule just for integration. This allocation is often repeated recursively at lower levels of decomposition of a large space platform.

Under SPA, computer-negotiated interfaces permit the elements of a complex system to transparently contribute information that accelerates the integration process by reducing or eliminating error-prone human interpretation. Electronic self-configuration/self-organization allows for rapid space vehicle construction. Additionally, the placement of sensors and actuators on the spacecraft is not restricted to specific, predetermined locations. In the terrestrial electronics industry, this capability is called "Plug-and-Play" (PnP). The approach fully supports an à la carte method of constructing arbitrarily complex arrangements of virtually any sensor or actuator type. Self-configuration/self-organization makes the network not only easy to expand and modify, but also robust to component failure from either natural causes or from deliberate attack.

The expected impact of Plug-and-Play goes beyond spacecraft manufacturing to increased manufacturing rates for satellite bus components. Through the production of scores or hundreds of units the economies of scale and the amortization of Non-Recurring Engineering costs, including iterative design, testing and certification, can fundamentally alter the profitability of satellite fabrication and integration. The result will be faster turns of satellite orders at a lower delivered price and a better profit margin to the manufacturer.

As the SPA concept advances, the set of internalized transport protocols will grow. The initial content of this guidebook will focus on standardization of ontology, the use of xTEDS to establish component (hardware and software) communications interfaces, the logical flow of SPA messages, functions of the SPA network, and the employment of existing data transport standards to form plug-and-play information interfaces. SPA standards complete the architecture with inclusion of physical interfaces.

1 Scope

This Guidebook provides an overview for spacecraft platform (system), subsystem, and component (including payload) developers with spacecraft plug-and-play architectures to promote rapid design, fabrication, integration, and test. Included is an introduction to SPA, providing an informative reference for the uninitiated reader. It also includes a summary of the SPA standards. The standard user is directed to the SPA standards for detailed requirements. In cases where material in this document differs from a SPA standard, the standard will take precedence.

2 Tailoring

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

3 Applicable Documents

The following documents contain provisions which, through reference in this text, constitute provisions of the SPA standards. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

3.1 Normative References

W3C XML 1.0	<i>Extensible Markup Language</i>
W3C XML Schema Part 1	<i>XML Schema: Structures</i>
W3C XML Schema Part 2	<i>XML Schema: Basic types</i>
AIAA S-122-2007	<i>Electrical Power Systems for Unmanned Spacecraft</i>
CCSDS 660.0-B-1	<i>XML Telemetry and Command Exchange (XTCE)</i>
CCSDS 850.0-G-1	<i>Spacecraft Onboard Interface Services – Informational Report</i>
ECSS-E-ST-50-12C	<i>SpaceWire – Links, Nodes, Routers and Networks, July 2008</i>
IEEE 1451 Standards family	<i>Standard for a Smart Transducer Interface for Sensors and Actuators</i>

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

6DoF	6-degrees-of-freedom
AIAA	American Institute of Aeronautics and Astronautics
APT	advanced plug-and-play technology
ASIM	appliqué sensor interface module
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials