Advanced On-board Control Procedure

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Overview

The **Advanced On-Board Control Procedure (AOBCP) product** is one of a set of technologies that allows to implement cost effective operation and control of a spacecraft. Together these technologies are called the Operations Avionic System. The AOBCP is a procedural sequencing software system which simplifies spacecraft operations, minimizes uplink product size, and allows autonomous operations aboard a mission without the development of autonomous flight software. It provides an automation mechanism for different missions such as manned or unmanned transportation, science laboratory mission, rendezvous and docking, reentry, etc.

It allows the execution of adaptive mission operations through on-board execution of re-configurable automated engineering and science procedures, authored in a high level language readily understandable to humans. The executed procedures are capable of interacting with the on-board (sub-)systems, payload devices and instruments through sending telecommands and receiving telemetry. They support also conditional execution and thus enable the spacecraft to be controlled autonomously with immediate reaction to contingencies such as failed telecommands and/or on-board failures, and to any other mission events.

The executed procedures are easier to develop than actual flight software and provide more flexibility than an equivalent on-board software implementation regarding their update and maintenance hence reducing the cost of the overall software development and operation. For instance they may replace software components that are likely to change as the project matures (e.g. Fault Detection, Isolation and Recovery, complex configuration sequences, etc.) or as mission changes, or for other reasons of convenience such as late trade-offs.

The AOBCP product is therefore appropriate to support the global application functions that provide mission management and vehicle configuration such as Fault Detection, Isolation and Recovery, system mode management, spacecraft configuration and equipment management, autonomy framework, etc.

It provides enhanced operational capabilities through modern and advanced features allowing logical activities being driven by on-going

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conditions and being reused and shared, and decision-making to be coordinated.

Applications

The AOBCP system supports the following major types of utilization contexts:

- On-board applications: in this context, procedures implement part of the basic functionality of the spacecraft and can be an integral part of the spacecraft design and as such their lifecycle is partly decoupled from the on-board software but still tightly linked to the system development process
- On-board operations: in this context, procedures are the on-board operator and are used to operate the spacecraft. Unlike the previous context, these procedures are not involved in the qualification of the spacecraft and their lifecycle is fully decoupled from the spacecraft system and consequently from the on-board software. This allows for their definition after launch without the need for system qualification.

Within these contexts, the typical applications of the AOBCP product encompass but are not limited to:

- Spacecraft manoeuvre operations including re-planning
- Spacecraft mode management and safe mode recovery assistance
- Spacecraft platform subsystem configuration such as power, thermal, routing (e.g. telemetry downlink and hardware configuration), etc.
- Spacecraft platform subsystem controlPayload and science instrument operations (configuration and control)
- Fault detection and response assistance
- Test automation, investigation and debugging
- Operations analysis and operational concepts development

Description

Configuration

The AOBCP product consists of an embedded flight software component (AOBCP Engine) and a ground-based compiler (AOBCP Compiler). Such configuration allows procedures to be generated, loaded and executed.

- A procedure source file containing human-readable script is

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generated using a standard editor or a tool providing similar capability (see "Further features")

- The compiler translates the script file into a loadable binary file
- The produced file can then be loaded by the AOBCP Engine

Features and characteristics

The features implemented by this product have been developed using the ECSS standard for On-Board Control Procedures as a guideline.
The AOBCP Engine allows multiple procedures execution within a single task context:

- Procedures are executed on-board in a protected environment
- A run-time responsible of the management of on-board procedures provides access to the on-board database, services and resources, and schedules the different procedures
- An extensible scheduler allows parallel and serial execution of procedures through round-robin scheduling algorithms
- Procedures can be loaded into a dedicated storage area of the on-board memory at any time prior to or during the mission and on-board file system is supported when available
- Procedures are structured and executed according to optional and mandatory blocks of instructions.

The language features a scripting language for procedure development on ground and a custom low-level language to support the execution of the procedures on-board. It supports the typical programming or interpreter language syntax:

- A large set of variable types, including integers, unsigned integers, floats, Booleans, strings and structured data types
- Arithmetic and time calculations, logical manipulations, and trigonometric functions
- Conditionals constructs and iteration loops
- Handling of symbolic constants and local/global variables
- Reference to on-board data (parameters, telecommands, events) by their names as defined in the spacecraft data repository
- Extensible to support further mathematical functions and user interaction capabilities (see "Further features")

The AOBCP preparation environment features a compiler which translates the procedures written in the scripting

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language into the representation used by the on-board engine i.e. bytecode:

- Based on a popular open-source infrastructure
- Translating commands and times using mission-specific pre-processing tools and tracking valid global variables and symbolic constants for the missionIEEE-802.1 D/w/s (Spanning Tree, Rapid Spanning Tree, Multiple Spanning Tree Protocol).
- L2 IEEE-1588v2 Precision Timing Protocol (PTP).

The AOBCP product prevents errors propagation, detects self-faults, and is easy for the ground and onboard autonomy systems to use.

Customization/tailoring capability

The AOBCP product is designed according to a custom-on-standard approach to efficiently mix and match functionalities allowing meeting the spacecraft mission and the target specific features and capabilities.
It follows a modular architecture so that easy integration and update of key functions as well as adaptation and sub-sequent increase of capabilities can be done to give even more flexibility.
The customization of the component may include, but is not limited to:

- Porting to various execution environments:
  - Current flight component configuration operates on LEON4 (European fault-tolerant processor) and RTEMS real-time operating system
  - Integration as standalone component into a partitioned system or integration to existing on-board software architecture
  - Component configuration parameters tailoring: e.g. maximum number of loadable procedures, maximum number of procedures executable in parallel, selection of the scheduling scheme, etc.
- Tailoring to the host on-board command and data handling implementation
- Tailoring of the capabilities and functions needs by the targeted mission and spacecraft

Integration to on-board software

The AOBCP flight component can be integrated into a classical on-board software architecture or can be deployed in a dedicated partition

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(time- and space- wise) of an ARINC 653 software system.
The AOBCP flight component tasks are executed cyclically and require that the software system hosting them ensures the CPU access necessary to meet their deadlines: typically they must have a higher priority than application tasks and must remain consistent with the other software system services they rely on.
The default command and data acquisition services, time access services, file services, message transfer services rely on the CCSDS Spacecraft Onboard Interface Services Area (SOIS) application layer.
The default controllability, observability and reporting services rely on the ECSS standard for Telemetry and Telecommand Packet Utilization (PUS).

Hardware requirements

CPU usage and memory footprint data on request.

Software requirements

The AOBCP flight component runs as an embedded task under RTEMS or a similar real-time operating system within the flight software.
The AOBCP compiler runs under standard Linux distribution.

Further features

Beyond the current configuration of the AOBCP product, a series of improvements and supplementary features are considered for implementation. They can be developed on request should their development planning not satisfy the constraints of the mission or spacecraft targeted.
Among the options are:

- Support of parameterized procedures
- Extension of the preparation environment with an authoring tool (a syntax highlighting parser is already under development), execution constraints checking function (static analysis), consistency checking function (w.r.t. engineering database) and validation tools (self-contained simulation, HIL, etc.)
- Handling of emergency procedures
- Support of other scheduling schemes
- Extension of the mathematical libraries, e.g.:
  - Bitwise manipulations and string operations
  - Filtering functions
  - Vector and matrix functions

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- Support of state machines to provide enhanced autonomous management of spacecraft complex operations
- Support of basic form of object orientation
- Capability to pack functions in order to provide libraries of commonly needed services

Software licensing

Commercial information on request.

Operations Avionic System products

- Advance On-board Control Procedures: application to Mission and Vehicle Management, FDIR for unmanned or manned spacecraft
- Cockpit Display System: application to monitoring and control of manned spacecraft
- Individual Control Aids: application to reduced workstation (e.g. for 3D video during docking, CDS back-up, support to complex operations, payload handling), personal display device for passengers, mobile maintenance operator (ground application), etc.
- Cockpit Evaluation Mock-up and Simulator: application to mission rehearsal (e.g. RVD), evaluation, training

Operations Avionic System applications

- ESA's Advanced Re-entry Vehicle (ARV)
- Turkish Aerospace Industries Inc.mission rehearsal (e.g. RVD), evaluation, training

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