# Annex II: Description of WP/PP activities of GSTP Element 1 "Develop"

## GEN – Generic Technologies

## CD2 - Structures, Mechanisms, Materials

**Ref. Number:** **GT17-579EC** **Budget (k€): 400**

**Activity Title:** **Simulation software for modelling structure/AOCS coupling**

**Objectives:** The objective of this activity is to develop a software toolbox to link structural modelling software with AOCS control software.

**Description:** Large space structures are expected to exhibit structural modes at low frequency likely to couple with the AOCS control system. The objective of this activity is to couple the structure mathematical model (FEM) with the AOCS control software to perform design, verification and validation activities. While a direct coupling of the FEM with the Functional Engineering Simulator (FES) that models the control system behaviour can serve for simulation purposes and play an important role in the validation process, an additional step is needed to develop linearised models that can be employed in the AOCS design and verification activities.

Such models need to capture the nominal dynamic behaviour as well as uncertainties in the dynamics' formulation and in the dynamical parameters. These need to be captured and quantified according to the specific modelling techniques used in control system design (typically Linear Fractional Transformations (LFT)). This would allow to model the interaction between a large 'flexible' structure with the attitude control system (including investigating the effectiveness of distributed attitude control hardware sensors/actuators).

This activity will develop suitable structural models for highly flexible structures to be accounted for in control design and verification activities.

The activity will encompass the following tasks:

- Review and select on-board uncertainty modelling techniques based on the LFT framework.
- Assess the dynamic and kinematic modelling requirements for a very large space structure.
- Implement detailed nominal as well as uncertain models of the main effects relevant to the modellisation of very large space structures. Degraded configurations considering potential structural failures as well as failures in AOCS sensors or actuators shall be considered.
- Validate such models against analytical (where possible) as well as experimental data.

**Deliverables:** Software, Technical documentation (including software user manual), Reports

**Current TRL:** 2 **Target TRL:** 4 **Duration (Months):** 18

**Application:** Space-based solar power and large space structures

**Proc. Policy:** C

**THAG Roadmap:** Relevant to the Roadmap AOCS and GNC Systems.

**Ref. Number:** **GT17-580EC** **Budget (k€): 650**

**Activity Title:** **Active local structural control of very large space structures**

**Objectives:** The objective of this activity is to develop a breadboard of a local active control system, which demonstrates the capability of locally regulating the stiffness of very large structures in space.

**Description:** Large space structures are expected to exhibit structural modes at low frequency likely to couple with the AOCS control system. For very large structures it is expected that the attitude control will be achieved by distributed sensors and actuators, which may potentially result in relative high loads and displacements. Past activities have shown the potential of local structural control by using strain sensors co-located with active elements for local structural stiffening (e.g. based on piezo technology).

This activity is expected to provide an assessment on the critical aspects of very large structures, including:

- Interaction between structure and AOCS (criticality of structure stiffness vs. mass).
- Feasibility to reduce structural resonance through passive and/or active structural damping.
- Criticality of pointing and stability requirements, e.g. for solar power generation maintaining sun-point for solar generator surface and Earth pointing for power transmission.
- ROM evaluation of internal loading on structure to ensure satisfactory capability of structural design, material selection and joining technologies.
- Feasibility for redundancy in the design and performance of very large structures, assuming potential failure in structure or structural joining elements as well as on AOCS sensors and actuators over the anticipated in-orbit lifetime.

In consideration of the above, this activity targets the development of a local active control system breadboard together with an on-ground testbed representative of very large structures in space to demonstrate this technology.

The activity will encompass the following tasks:

- Identify candidate sensing and stiffness regulators suitable for local strain sensing and stiffening.
- Assess and optimise the integration of strain sensing and stiffness regulators into structural elements in view of optimising the local controllability of stiffness.
- Design a distributed control system that drives the local stiffening systems to achieve global stabilisation and control goals.
- Define a suitable verification and validation process for the designed distributed control system.
- Define and setup a ground testbed representative of very large structures in space.
- Demonstrate the distributed control system on a suitable scaled breadboard, adapted for laboratory environment and deployed on the ground testbed.

**Deliverables:** AOCS breadboard, Ground testbed, Technical documentation, Reports

**Current TRL:** 2 **Target TRL:** 4 **Duration (Months):** 18

**Application:** Space-based solar power and large space structures

**Proc. Policy:** C

**THAG Roadmap:** AOCS and GNC Systems (2024)
Consistent with activity B26 “Active local structural control of highly flexible structures”.

## CD4 - Electric Architecture, Power and Energy, EMC

**Ref. Number:** **GT17-581EP** **Budget (k€): 2,000**

**Activity Title:** **Modules for PCDU based on APA standard**

**Objectives:** The objective of this activity is to design and develop the five modules that will be part of the Power Conditioning and Distribution Unit (PCDU) based on the Advanced Power Architecture (APA) standard.

**Description:** APA is an initiative to standardise the PCDU and make it fully compatible with the Advanced Data Handling Architecture (ADHA). The APA standard covers the mechanical frame, the electronic backplane, the internal unit communication system and the module functionality. The standard allows to build a PCDU with modules produced by different manufacturers and to be integrated in a common unit frame.

The objective of this activity is to develop a second source of the APA modules set compliant with the standard defined under the APA system activity (presented in the document with reference ESA/IPC(2024)192), in order to eventually improve the performance, reduce the time to market and enable larger production quantities of PCDUs. The availability of interchangeable and interoperable PCDU modules by multiple manufacturers will also enable more competitive PCDUs.

The aim of this activity is the development of the following modules:

- Serial Switching Shunt Regulator Module (S3R-M): is one of the topologies used for solar array power conversion and its function is to receive the power from each section of the solar array, perform the conditioning function and deliver the power to the main power bus with the adequate power quality.
- TM/TC Controller Module (CTR-M): is responsible for receiving telecommands for the PCDU and sending back telemetry with the internal parameters and status signals. It is based on a CANBUS external and internal communication bus The module shall also contain the Auxiliary Power Supply (APS) for the PCDU. The APS shall provide all internal voltage rails needed to power all APA modules. The module shall have two independent chains on TM/TC and APS, nominal and redundant so that one single module is needed for a one failure tolerant unit. A key aspect is that the Controller Module shall be compatible with an ADHA unit.
- Distribution Module (DIS-M): is responsible for distributing electrical power to “power users” via current protected lines. Current protections limit the amount of power that any unit can draw from the bus. In case of overload or short circuit in any unit or instrument, the so called LCL/RLCL/HLCL (Latching Current Limiter/Retriggerable LCL/Heater LCL) will protect the bus by limiting the current and allowing all the other units to operate nominally. The LCL module shall include 24 (TBC) LCL ranging from class 1 to class 10, 6 RLCL (TBC) ranging from class 1 to class 5, and 72 (TBC) heaters outlets, grouped and protected by a convenient TBD number of HLCLs.
- Battery Management Module (BAT-M): is responsible for controlling the main power bus voltage. This module is the heart of the PCDU and must be Single Point Failure Free (SPFF) in a dynamic way. The main functions implemented in this module are the battery isolation switch, the generation of the Main Error Amplifier signal to be transmitted through the backplane in a reliable way, the processing of the Separation Straps Signals and the tuning of the Power Bus impedance.
- Deployment Module (DEP-M): is responsible for driving actuators that release deployable structures (antennas, solar array wings, booms) that are mechanically hold down during launch. This module shall be able to drive all deployment actuators used in satellites, including thermal knives, non-explosive actuators, pyro devices, pin pullers and frangibolts.

Each module will have a maximum budget of 400 k€.

The main bus voltage is 28 V, with a minimum and maximum values of 22 V and 37 V respectively (TBC). The maximum power level per module is 1800 W (TBC).

All five modules shall comply with the APA standard and rely on the basic functions provided by the other modules. The modules shall be compliant with the APA mechanical frame, the APA backplane and the APA ICDs. The key results from all activities related to APA shall be shared among the consortium members to enable a seamless integration and a fair development of the standard. All contractors of APA related activities shall support the APA consortium (primes and the unit integrators) for the unit and system level activities.

The following tasks are foreseen for each module within this activity:

- Functional design.
- Electrical design and analysis.
- Thermal and mechanical design.
- Manufacturing.
- Module functional and electrical testing.
- Support for module integration in an APA unit
- Participation in APA related workshop and public reviews.

**Deliverables:** S3R-M, CTR-M, BAT-M, DEP-M, DIS-M breadboard/prototype modules, Reports

**Current TRL:** 3/4 **Target TRL:** 5/6 **Duration (Months):** 24

**Application:** All missions.

**Proc. Policy:** C

**THAG Roadmap:** Relevant to the Roadmap Power Management and Distribution.