Space Project Management

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(Based on 2007 lectures by Petrus Hyvönen)
Outline

■ Objectives and requirements
■ Project management tools
■ ESA project phases
■ General comments
Mission Objectives

- The mission objectives define the goals and requirements of the mission
  
  - To investigate Venus atmosphere and its coupling to the solar wind to understand the development of Venus atmosphere and hydrosphere

(Note feedback all the way to the objectives)
Space Mission Analysis and Design Process

- Note that requirement is defining what is to be done, and not how.
- Requirements are quantitative measurements of how well objectives are met.

<table>
<thead>
<tr>
<th>Typical Flow</th>
<th>Step</th>
<th>Section</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Define Objectives</td>
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<tr>
<td></td>
<td>A. Define broad objectives and constraints</td>
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<td></td>
<td>B. Estimate quantitative mission needs and requirements</td>
<td>1.4</td>
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<td></td>
<td>Characterize the Mission</td>
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<td></td>
<td>C. Define alternative mission concepts</td>
<td>2.1</td>
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<td></td>
<td>D. Define alternative mission architectures</td>
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<td></td>
<td>E. Identify system drivers for each</td>
<td>2.3</td>
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<td></td>
<td>F. Characterize mission concepts and architectures</td>
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<tr>
<td></td>
<td>Evaluate the Mission</td>
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<td></td>
<td>G. Identify driving requirements</td>
<td>3.1</td>
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<td></td>
<td>H. Evaluate mission utility</td>
<td>3.2</td>
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<td></td>
<td>I. Define mission concept (baseline)</td>
<td>3.3</td>
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<tr>
<td></td>
<td>Define Requirements</td>
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<td></td>
<td>J. Define system requirements</td>
<td>4.1</td>
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<tr>
<td></td>
<td>K. Allocate requirements to system elements</td>
<td>4.2-4.4</td>
</tr>
</tbody>
</table>
Top level mission requirements

<table>
<thead>
<tr>
<th>Functional Requirements</th>
<th>Operational Requirements</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Mission Duration</td>
<td>Cost</td>
</tr>
<tr>
<td>Coverage</td>
<td>Availability</td>
<td>Schedule</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>Timeliness</td>
<td>Regulations</td>
</tr>
<tr>
<td>Secondary missions</td>
<td>Survivability</td>
<td>Political limits</td>
</tr>
<tr>
<td></td>
<td>Data Distribution</td>
<td>Environment</td>
</tr>
<tr>
<td></td>
<td>Data Content</td>
<td>External interfaces</td>
</tr>
<tr>
<td></td>
<td>Data Form</td>
<td>Development</td>
</tr>
<tr>
<td></td>
<td>Data Format</td>
<td>Constraints</td>
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<tr>
<td></td>
<td></td>
<td>Spacecraft Disposal</td>
</tr>
</tbody>
</table>
## Science objective vs Payload instrument matrix

<table>
<thead>
<tr>
<th>Scientific Objective</th>
<th>Payload Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venus atmosphere – solar wind interaction</td>
<td>X</td>
</tr>
<tr>
<td>Direct measurement of escaping ions</td>
<td>X</td>
</tr>
<tr>
<td>Water escape in the past</td>
<td>X</td>
</tr>
<tr>
<td>Aurora</td>
<td>X</td>
</tr>
<tr>
<td>Acceleration processes</td>
<td>X</td>
</tr>
<tr>
<td>Lightning</td>
<td>X</td>
</tr>
<tr>
<td>Super-rotation</td>
<td>X</td>
</tr>
<tr>
<td>Greenhouse effect</td>
<td></td>
</tr>
<tr>
<td>Dawn-dusk asymmetry</td>
<td>X</td>
</tr>
<tr>
<td>Meso-scale properties</td>
<td>X</td>
</tr>
<tr>
<td>Magnetic field</td>
<td></td>
</tr>
<tr>
<td>Volcanic activity</td>
<td>X</td>
</tr>
<tr>
<td>Kinetic effects of the solar radiation</td>
<td>X</td>
</tr>
</tbody>
</table>

- Ion mass spectrometer
- Ion and electron spectrometer
- Plasma wave/lightning detector
- Langmuir probe
- Magnetometer
- ENA spectrometer
- Mass-resolving driftmeter
- Near IR imaging spectrometer
- UV/visible photometer
- Sub-satellites
- Plasma sounder
- Camera
Strawman Payload

- First payload that is used as a baseline in the design of the spacecraft
- Will be changed during a formal call
- Important to early get a design of the spacecraft and understand the requirements

<table>
<thead>
<tr>
<th>Instruments</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass resolving ion spectrometer</td>
<td>5</td>
</tr>
<tr>
<td>Electron &amp; ion spectrometer</td>
<td>2</td>
</tr>
<tr>
<td>Wave/lightning detector</td>
<td>2</td>
</tr>
<tr>
<td>Langmuir probe(s)</td>
<td>1</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>0.5</td>
</tr>
<tr>
<td>ENA spectrometer</td>
<td>2.5</td>
</tr>
<tr>
<td>Driftmeter with mass resolution</td>
<td>3</td>
</tr>
<tr>
<td>Subsatellites</td>
<td>16</td>
</tr>
<tr>
<td>Subsatellite release/support system</td>
<td>3</td>
</tr>
</tbody>
</table>

**Atmospheric instruments**

- Near IR imaging spectrometer                     | 10 |
- UV/visible photometer                            | 3  |
- Radio science experiment                         | 0  |

**Total Mass:** 48 kg
Project management tools

- Work breakdown structure
  - Total project work structured
- Gantt Chart
  - Work as a function of time with critical links
- Organizational chart
- Integrated models
Work package breakdown & Work package description

- On a large project, the work should be broken down into manageable subunits (work packages).
  - Tree structure ensures all work packages sum to 100% of task.

- A work package description:
  - is measurable and manageable in its scope
  - is allocated to only one manager
  - results in supply of products or documents
  - identifies all inputs and outputs, including interfaces with other tasks or WPs
  - clearly identifies planning constraints
Work package breakdown – example
Work package description – example

<table>
<thead>
<tr>
<th>PROJECT:</th>
<th>CHIP SCALE COOLERS</th>
<th>W.P. REF: 1400</th>
</tr>
</thead>
<tbody>
<tr>
<td>W.P. TITLE:</td>
<td>Development Planning</td>
<td></td>
</tr>
<tr>
<td>CONTRACTOR:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAJOR CONTRACT:</td>
<td>System Engineering</td>
<td></td>
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<tr>
<td>START EVENT:</td>
<td>Kick-off</td>
<td></td>
</tr>
<tr>
<td>END EVENT:</td>
<td>Final delivery</td>
<td></td>
</tr>
<tr>
<td>W.P. MANAGER:</td>
<td>Petrus Hyrönén</td>
<td></td>
</tr>
</tbody>
</table>

OBJECTIVES:
To establish and maintain development plans for the chip-scale cooler demonstrator

INPUT REQUIRED TO START:
- Kick-off or authorization to start
- Authorization to proceed with proposed objectives

TASKS INCLUDED:
- Establish the development plan for chip-scale coolers
- Maintain and update the development in a controlled way through the development process
- Compilation of test and verification plan

OUTPUT:
- Detailed development plan for chip-scale coolers
- Contribution to design reviews and final report
Schedule

As a minimum, the baseline schedule contains:

- key milestones
- descriptions of the activities
- start and finish dates of activities
- duration of activities
- identification of the critical path activities
Organizational Chart

- Clear and unambiguous definition of individual roles, responsibilities and authority
- Both internal and external to the organization

![Organizational Chart Diagram]
Concurrent engineering is a method to make early concept designs

- "Gather all in same room, have a boss, and make sure it all agrees in a semi-formal way"

Tested by ESA, NASA and many universities with successful results at early project stages

Integrated models are a central tool in this method

- Collect and link calculations, values and other information
- Enable all to access, modify and inspect
- Uses COTS software – Excel
  - Commercial Off The Shelf
### Integrated Model Example

- **Tabs for different subsystems**
- **Colorcoding for defining value properties**
- **References to external sources**
- **Possibility to define output / input variables**
- **Simple version handling**

#### Structure

**Solar Intensity**
- Distance from Sun: 0.7233 AU
- Intensity at Earth: 1358 W/m²
- Intensity at Distance: 2596 W/m²

**Solar Panels**
- Spacecraft diameter: 2.3 m
- Spacecraft Height: 0.8 m
- Panel Cross Section: 1.84 m²

**Power Generation**
- Total Panel Area: 1.84 m²
- Coverage ratio: 0.6

**Silicon**
- Thickness: 1492 μm

**GaAs**
- Thickness: 1893 μm

**Multilayer**
- Thickness: 269 μm

**Total Panel Efficiency**: 896
**Total Solar Power**: 401 W

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**Reusability**

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**Tabs for different subsystems**
Cost estimation

- Cost estimation needs to rely on good knowledge or good assumptions
  - Use previous missions and make a range of what seems reasonable
- Parametric model exists for common types of spacecraft
  - The applicability of these can be discussed
  - SMAD has a simple model for small satellite cost estimation
A phase is a group of activities

- advances a project from one milestone to another
- often ended by a formal review that confirms if the work has been done follows the requirements
Phase 0: Mission Analysis and Needs Identification

- (NASA terminology: pre-phase A)
- Identification and characterization
- Expected performance
- Assessment of operating constraints
  - in particular: physical and operational environment,
- Identification of possible system concepts
- Preliminary assessment of project management data (organization, costs, schedules)
- End result: specification of the mission concept

- At the end of phase 0, a Mission Definition Review (MDR) can take place
  - (NASA terminology: Mission Concept Review, MCR)
Phase A: Feasibility

Finalize needs expressed in phase 0 and propose solutions

- Quantify and characterise critical elements for technical and economic suitability
  - explore various possible system concepts
  - compare these concepts against the needs
    - determine levels of uncertainty and risks
  - estimate the technical and industrial feasibility,

- Identify constraints:
  - costs, schedules, organisation, utilisation (operations, implementation, maintenance),

- At the end of the phase A, the Preliminary Requirements Review (PRR) is conducted
  - (NASA terminology: Mission Definition Review, MDR)
Phase B: Preliminary Definition (Project and Product)

- Select technical solutions for system concept selected in phase A
  - acquire a precise and coherent definition (performance levels, costs, schedules) at every level

- System Requirements Review (SRR)
  - Initial identification of ‘Make or buy’ alternatives

- Confirm feasibility of the recommended solution

- At the end of phase B:
  - Preliminary Design Review
Phase C: Detailed Definition

- Detailed study of phase B solution
  - production of representative elements
  - detailed definition of system and components
- Allows a definitive ‘make or buy’ decision
- Allows confirmation of the test and qualification setup
- Allows preparation of phase E activities.

At the end of this phase, the Critical Design Review (CDR) is conducted.
Phase D: Production/Ground Qualification Testing

Phase D is the end of the system development.

- Ground qualification testing verifies:
  - technical conformity of the components against the requirements (*design qualification*)
  - aptitude to be used operationally (*operational qualification*)
  - identification of the functional and operational margins.

Phase D ends with the Acceptance Review (AR)

Phases C and D are usually inseparable
Phase E: Utilisation

- Launch campaign, launch and in-flight acceptance of space elements
- Operation and maintenance of the system, feedback.
- Can be divided into two sub-phases:
  - E1: test and commissioning
  - E2: utilisation
This course

- Designing to a pre-phase 0 level
  - Don’t need, e.g., detailed circuit diagram of electronics
  - Do need to demonstrate that the system could be built, and what it would be able to do if it were built

- Get organized!
  - Define roles and responsibilities
  - Have a plan for how to meet deadlines
  - Don’t get too far ahead of yourselves
This course

■ ”Phases”
  ● Gathering questions
    ▪ Meeting with experts: week of April 21
  ● Preliminary strawman payload
    ▪ Draft chapters May 16
  ● Iterating
    ▪ making into a consistent story
    ▪ Making ”sellable”
End of the lectures
(Next: learning by doing)

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