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SUPPORTING MODEL PAYLOAD SELECTION FOR SCIENCE MISSION FORMULATION

Andy Braukhane
German Aerospace Center (DLR), Germany, andy.braukhane@dlr.de

Antonio Martelo
German Aerospace Center (DLR), Germany, antonio.martelo@dlr.de

When confronting the design of a new space science mission the ideal situation would be one where a team of scientists would set the scientific goals and define a model payload. Subsequently, an engineering team would define the constraints this payload imposes on the mission analysis, spacecraft design and ground segments. But this is much more complex since limitations imposed by system-related elements have also an impact on the payload design. Because of this, both the scientific and engineering teams must work together and be capable of redefining scientific requirements so as to obtain a feasible design that does not compromise the essential objectives of the mission. For this process to be seamless, members of the scientific team should have some understanding of the technical issues, and members of the technical team should have a knowledge base that allowed them to understand the critical science issues. In reality, the fact that in a (e.g. concurrent) design study there are rarely payload developers present in either group tends to create a situation where the science team focuses on maximizing functionality, whereas the engineers target a robust system, and neither are able to size and define the payload and its impact on the system in a rapid and realistic way. To aggravate the situation, there are presently no tools, nor any known rules or relations between objectives and instruments that can help in the preliminary modelling of multiple payload sets. A study at the DLR Institute of Space Systems is currently ongoing to unearth said relations if they exist, with a long term goal of developing system engineering tools which can help in the preliminary design process for scientific exploration missions. The present paper recalls the problems and processes during the preparation of a science mission, especially in the European environment. It outlines how information from past missions could lead to a more robust preliminary system design through the use of dedicated analyses tools which propose potential instrument combinations, and can increase mutual understanding between scientists and engineers. This paper describes the steps of DLR's attempt to better organize such activities, and presents some preliminary results about instrument evolutions, trends and relations, based on the initial historical data gathering phase. These constantly evolving results will be later used to create tools for e.g. model payload proposals and system requirement derivation.

I. INTRODUCTION

Through scientific space exploration, new fundamental knowledge has been gained and new fields of research have been opened. Spacecraft have explored the solar system, giving us insights into the composition of the Sun, as well as its behaviour and its cycles. Understanding of our neighbouring planets and of the structure of our solar system itself, such as we could never hope to attain from Earth, has been achieved by different missions over the years.

Space telescopes have made possible the observation of the universe in areas of the electromagnetic spectrum that are not visible from the ground due to atmospheric blocking.

Nearby measurements, made in planetary flybys or by orbiters, have increased the precision of our measurements and provided us with data unattainable from Earth, such as the ground temperature of Venus – which confirmed the theory of there being a greenhouse effect – or the magnetic fields of the different planets of our solar system.

From the search of Earth-like planets orbiting other stars by the Kepler mission, the interplanetary travel of the Voyagers 1 and 2, the amazing observations made by space observatories such as the Hubble Space Telescope, or the different experiments carried out which have pushed the frontier of scientific knowledge ever forward, the sheer diversity of space science missions dwarfs the imagination.

II. PROBLEM STATEMENT

When initially confronting the design of the spacecraft for a new scientific mission, many different elements, subsystems and interfaces must be studied, and multiple perspectives make initial considerations even more complex.

From the science angle, the driver is to increase functionality and obtain as much data as possible. From the engineering viewpoint, the objective is to build an optimal solution which allows for a robust system, even if it might reduce functionality to a degree. There is an "us versus them" syndrome which has to be broken [1].

Throughout the entire design activity, these two perspectives have to be balanced, whilst at the same time different solutions which can fulfil the mission goals must be considered. Over time, a number of tools and rules have been developed to deal with the particularities of the system design for most spacecraft sub-systems. This is not so for the payload.

The fact that the payload of a scientific mission is typically ad-hoc makes it an element difficult to deal with in preliminary designs, especially since neither the scientific party nor the engineering party are necessarily payload developers. There are many uncertainties when trying to predefine a payload for a specific set of scientific objectives; there are no rules as to what set of instruments are better for a particular type of mission, the maturity of different instruments inherited from previous missions varies, impact or influences between different instruments are not always obvious.

As of today, no drivers or relations between scientific objectives and instruments, or limitations and affinities in the use of different instruments in a single payload, have been defined and the payload is generally considered as an element to be tailored to the specific mission to be undertaken.

III. OUR MOTIVATION

III.I Concurrent Engineering (CE) activities

At the *German Aerospace Center (DLR) – Institute of Space Systems* we are operating a "Concurrent Engineering Facility (CEF)" which is a modern working environment making use of tools, models, processes and the possibility of co-locating an entire expert team for feasibility studies [2].

This facility, shown in Fig. 1 below, is open for internal activities as well as for externally requested design sessions.

Fig. 1: Concurrent Engineering Facility at DLR

The use of the Concurrent Engineering (CE) methodology is furthermore characterized by the involvement of all relevant disciplines, including engineers, the customer and related scientists.

It provides connected work stations for up to 13 disciplines in the main room and offers two splinter-meeting offices for 'off-line' group discussions using e.g. Smartboards™, flip charts and additional work stations.

This iterative, interactive and multi-disciplinary approach is already advantageous compared to the traditional development processes applying sequential or centralized engineering approaches [3].

However, although this structured way of 'doing systems design' incorporates many useful aspects of how a design team could effectively work together, a lack of structure, design guidelines and detailed best practices has been identified on our side when preparing science missions for e.g. European calls to tender.

In addition to the exploration missions which have been analysed primarily for German national activities (i.e. AMSAT Moon, AMSAT Mars as well as the e.g. DLR-internal TRIP-, TiNet- and also CERMIT projects) three CE-studies have been carried out as preparations for potential contributions to an ESA-led scientific flagship mission:

(1) Mobile Asteroid Surface Scout (MASCOT)
(2) Solar Magnetism Explorer (SolmeX)
(3) Castalia - Main Belt Comet (MBC)

The related three space systems, which are presented with an initial design in Figure 2 below, have been conducted for the medium-class (M)2-, 3- and 4-call, respectively. For the present work, they have been identified as concrete examples for the identified need of improvements related to the model payload selection process.

On the following page, there is a brief description for each of the CE-studies.

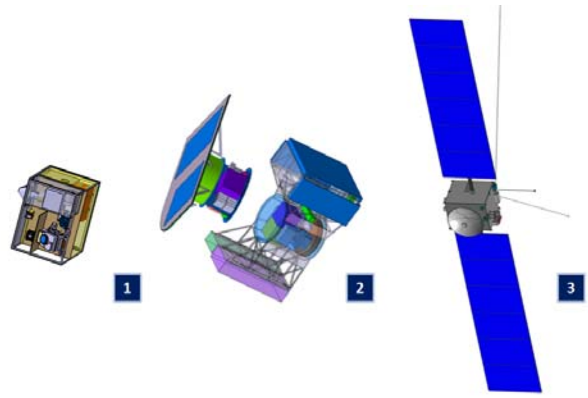

Fig. 2: ESA science-call related CE-studies at DLR

III.II Mobile Asteroid Surface Scout (MASCOT)

In April 2009, DLR prepared a proposal for a lander to be integrated in the ESA Marco Polo mission. In a dedicated CE-study scientists and engineers worked out three different concepts with different sizing and number of payloads [4].

Due to programmatic aspects the initially proposed options (i.e. with a total mass of 100kg, 70kg, 30kg) have been downscaled and re-designed to a 10kg lander within three follow-on studies in the course of the following two years until phase B of that project.

The final idea was to come up with a self-standing landing package which could serve different scientific missions to other near-Earth objects. This included a reduction of two proposed payload sets (from the smaller options with a mass of approximately 14kg and 6kg, excluding support structures and robotic arms) down to 3kg only.

The latest version has been finally adapted to the Japanese Hayabusa-II mission which is supposed to launch end of 2014.

The MASCOT lander, renamed from *Marco Polo Surface Scout* to *Mobile Asteroid Surface Scout*, now contains a set of four instruments including a camera, a magnetometer, a radiometer and a combined optical microscope and infrared spectrometer [5].

The initial version had foreseen up to 14 instruments for the model payload and was a result of an intensive trade-off with several ranges of priorities.

III. III Solar Magnetism Explorer (SolmeX)

A science community led by the Max-Planck Institute for Solar System Research, elaborated on a science mission proposal for the 3rd ESA Medium-class (M3) call in 2010.

This was done in collaboration with engineers from DLR, using the Concurrent Engineering environment to ensure a feasible and consistent design of the space system (see [6]).

The initial design included two system elements, an Occulter- and one Coronagraph spacecraft (S/C). The latter contains 5 instruments, a scanning UV spectro-polarimeter, an EUV imaging polarimeter and a chromospheric magnetic explorer (all accommodated on the S/C disc) as well as a coronal UV spectro-polarimeter and a visible light & infrared coronagraph (both accommodated 'off-limb' for non-solar eclipse measurements).

During this study - probably due to the clear scientific focus - there was a relatively clear picture of the required payload and not many additional iterations were necessary. However, some minor re-design activities concerning the volume/accommodation space and P/L component combinations for power and mass savings still had to me made.

III.IV Castalia Main Belt Comet (MBC) Mission

The last ESA-related science mission which has been studied is the Castalia mission to an "active asteroid" or so-called "Main Belt Comet (MBC)". In spring 2013, a team of scientists and engineers were collaboratively designing the space system which shall be capable to fulfil the proposed mission objectives while still being compliant with the ESA M-class requirements. Prior to the study-phase, which took around two full weeks, a set of instrument had been worked out. This process included their categorization, prioritization (in two groups) and parameter gathering. This mission includes a model payload consisting of five in-situ and five remote sensing instruments [7].

Here, the selection process was rather tricky due to the variety of science goals and potential combinations of instruments. Careful trades with the entire science team plus engineering representatives had been made to compare all proposed instruments with the objectives and to find the most suitable set which still requires being in-line with an initial mass budget of the overall mission. Two priority ranges have been defined to maintain flexibility throughout the design process which took place in the DLR CEF with an international team of scientists as well as engineers from OHB and DLR.

IV. THE TRADITIONAL PROCESS

For a European "Cosmic Vision" science proposal there is a well-defined process with the following main phases, according to [1] and outlined in Figure 3 below:

- Proposal phase
- Assessment phase
- Definition phase
- Implementation phase

The here discussed project focusses on the proposal phase, i.e. the initial analysis of the scientific and technical feasibility. However, considering continuous future improvements, the assessment and definition phase might benefit from the proposed approach, too.

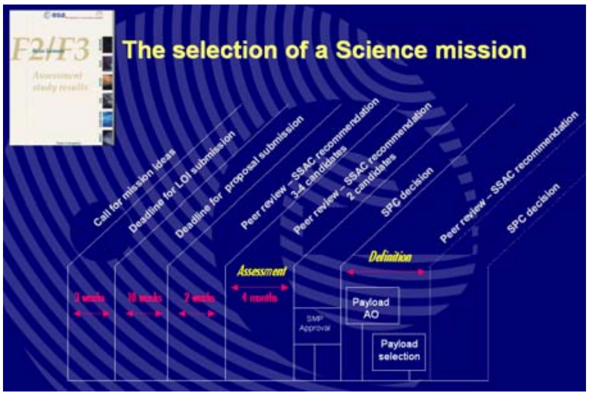

Fig. 3: Overview - ESA science mission selection [1]

IV.I Proposal-Phase

Starting with a "call for proposals" the science community is requested to initially provide a Letter of Intent, and then a proposal which summarizes the scientific objectives of a new mission, including their justifications, comparisons with other missions, performance trades, preliminary requirements and a first system design. The time-frame is about 3 months and the results have to fit amongst others into the given cost- and mass envelopes provided by ESA.

As a reference or guideline, the community receives as part of the call relevant information to the requested proposal content (i.e. what to deliver) as well as a set of additional information from past missions, their main system parameters, launch vehicles and payloads.

Table 1 below shows an example of a mission and instrument list for the M3-call released in 2010 [8]:

Mission and Instruments		Wave band	Type	Mass [kg]	Average power [W]
XMM	EPIC	0.10 to 15 keV	Imager	235	240
	RGS	0.35 to 2.5 keV	Grating spectrometer	248	140
INTEGRAL	IBIS	20 keV to 10 MeV	γ -ray imager	677	240
	SPI	20 keV to 8 MeV	γ -ray spectrometer	1309	384
	JEM-X	3 to 35 keV	X-ray monitor	68	62
Gaia	3 integrated instruments	250 to 1000 nm	Spectrometer, photometric and astrometric instrument	740 (PLM mass)	1486
JWST	NIRSpec	0.6 to 5 μm	Spectrometer	276	30
	MIRI	5 to 28 μm	Imager, spectrograph, coronograph	126	65

Table 1: Example of instruments and missions list provided by ESA as reference information for a medium-class proposal phase (i.e. here: ESA's astronomy and fundamental physics missions) [8]

IV.I Assessment-Phase

This phase is an ESA-internal activity, usually making use of the Concurrent Design Facility in which the most promising proposals will be evaluated and assessed in more detail. The timeframe is between 4 and 9 months. One major outcome – next to the overall feasibility approval and the implementation scenario - is the Payload Definition Document, still containing a model payload. At the end of this phase, one or two missions will be transferred to the definition phase.

IV.I Definition Phase

This industrial and competitive period takes about 2-3 years in total and lasts until the completion of the project phase B1.

In the frame of this activity, already at an early stage, the final payload selection has to be done, which includes also the negotiation with the Principal Investigators and the creation of an Experiment Interface Document which is a (living) baseline of their requirements and hence, the P/L-to-system interaction.

IV.I Implementation Phase

Lasting approximately several years until launch, this industrial, non-competitive phase covers all remaining work focussing on the procurement, integration and test of components and system elements. The "payload selection" does not play a central role here since their design and combinations have already been defined in the beginning of the previous phase.

V. PROJECT OVERVIEW

V.I Objectives

The objective of this study is to examine the different scientific missions carried out in the past, investigate the payloads which have been used for science missions up to date, build a database relating missions and instruments, and study the driving parameters so as to identify payload/bus relationships which can be used for preliminary design of scientific missions, or for initial sizing considerations when assessing a mission in early design stages.

The definition of such relationships and drivers, along with a detailed database of instruments (e.g. as an elaboration of data seen in Table 1), can be later used to design system engineering tools which will help to predefine a payload based on the scientific objectives of a mission. In turn, this can be used as an input towards the sizing of other subsystems of the spacecraft, providing a support for the formulation of the mission.

V.II Study Scope / Phases

As of today, sources of information and relevant parameters which allow us to make the maximum number of relevant connections as possible, have been identified, data has been collected for most of the international science flagship missions and for over one hundred additional missions related to e.g. Earth Observation missions in Low Earth Orbit (LEO), Communication satellites or Technology demonstration systems, which could provide useful information about instrumentation. Furthermore, some basic tabulation- and statistical tools have been developed, and an initial validation has been performed.

The present study is divided into four major phases, with the project already being in phase (2):

(1) Research and data collection (continuously on-going and to be updated)
(2) Data linking and comparison (e.g. payload and system/bus parameter)
(3) Definition of rules, relationship and methods
(4) Testing and (initial) application of derived methods and tools (e.g. calculation sheets)

Whereas the first phase requires constant updates, the next step is the cross-comparison of parameters for performance sensitivities or other data patterns.

VI. METHODOLOGY

As the main body of the investigation is focused towards relating missions and instruments and thereafter studying the driving parameters so as to ascertain what relationships and connections can be found, this applied research would be catalogued as a "relational study".

This is a study which investigates possible relations between parameters to establish if a correlation exists and, if so, to what extent.

It follows a mixed approach, where the ***qualitative*** component would be contributed from the relations found between different parameters (e.g. mutual or one sided influence between a certain system and payload parameters, which could be caused by a causal relation), and the ***quantitative*** component would be provided through statistical results (e.g. the standard deviation and mean value of a certain parameter, or the degree of correlation, whether positive or negative, between various parameters).

VI.I Data Sources

The sources of information used where chosen for their reliability, mostly belonging or being derived from international space agencies, and some relevant portals, books and papers, such as ESA's Earth Observation (EO) portal, the ESA/CEOS EO handbook, "Observation of the Earth and its Environment" [9], UCS satellite database.

VI.II Data Organization

The information extracted from the data sources was organized in two different data-bases, one structured according to each individual mission, and another according to the instrumentation.

The configuration of these databases included four types of fields:

- Basic parameters (e.g. mass, power consumption, data rates)
- Parameters considered important to the specific database, or interesting (e.g. orbital information for the mission database, or performance information for the instrument database)
- Fields which provided extra-information that might be useful, such as the types of measurements carried out by the mission, the URL of interesting websites related to the mission, the description of mission goals and science objective's,
- Categories according to an ad-hoc list defined for this project.

The definition of categories was of paramount importance in this study, as they provided the basis for filtering relevant information and conduct the search for interrelations between missions and instruments.

The ***mission categories*** are defined under three main classifications:

- Applications (e.g. Science, Earth Observation, Technology development),
- Mission Target (e.g. Moon, Lagrangian points, Sun),
- Mission Classes (i.e. Small, Medium and Large; based on their launch mass).

The ***instrument-related categories*** on the other hand included:

- the Instruments' nature (direct-/remote sensing),
- the operational manner (passive/active),
- and the Instrument type (e.g. particle detectors, plasma Instruments, dust detectors, imaging Magnetometers, Spectrometers).

VI.II Data Utilization

In the end, the concrete use of historical mission- and payload design parameters are only one part of the project. They are self-standing and provide the main information to quickly assess the type and number of instruments to be proposed. However, for completing the overall formulation process, the link to the mission objectives and goals should be established by directly deriving specific measures, which then will be further translated into requirements for the P/L selection. This is likely the most challenging and uncertain part.

VII. DATABASE / TOOL

An Excel file was used for the collection and formatting of the information. It includes the two database worksheets for missions and instruments, and three additional worksheets which provided the tools that helped to automate the tabulation process, creating amongst others a summarized table, diagrams and preliminary statistical analysis, based on a number of selectable criteria. A block diagram is shown in Fig 4.

On the following page, there is a brief summary of the different sheets and their purpose.

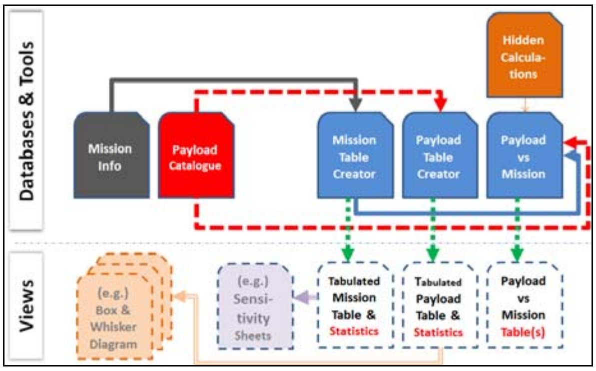

Fig. 4: Overview of the database workbook, including the relation of the various functional and (optional) data visualization spreadsheets.

VII.I Mission Information

As a primary source of information, there is a mission information database including over 2000 entries of missions as derived from the data sources previously identified (after cleaning of possible repetitions, irrelevant elements, or missions without sufficient information).

At this stage, the information is not complete as collecting the data is a laborious task which has to be tackled with care.

This worksheet includes not only science missions, which are the focus of our study, but other types too (e.g. telecommunication satellite systems, technology development platforms), providing a reusable database which can be later used for other studies, covering most international space agencies as well as many space entities and companies.

However, since collecting data related to science missions is difficult and sometimes there is contradictory information, the data will be always subject for further maintenance and updates, especially when new mission will be realised. So far, about a hundred science missions (with varying amount of data) provide the baseline for the “proof of concept” related to the present work.

VII.II Payload Catalogue

For instrument-specific analyses, there is a payload catalogue included which is a database consisting of over 130 instruments (so far) from strictly science-related missions, covering all the types of instruments previously categorized. However, in order to provide a better picture of the various instruments, the catalogue will not be limited to science missions but especially updated with current and former Earth Observation payload data.

VII.III Tool-Sheets

Three filtering and data-organizing tools have been developed so far, including:

- ***Mission Table Creator:*** As one tool to facilitate the analysis of missions, this worksheet creates a list of missions that comply with up to four selectable mission categories. Additionally to this data tabulation, the tool calculates statistical parameters to help with the analysis, and displays the possible correlations between different combinations of variables.
- ***Payload Table Creator:*** This tool is similar to the first one, but it focuses on the instrument database. In the same way as the Mission Table Creator, it tabulates a list of instruments that comply with up to two selectable payload categories and provides statistical parameters and studies the possible correlations between different combinations of variables.
- ***Mission vs. Payload Table Creator:*** As a final tool, this worksheet creates four tables that cross missions and payloads to facilitate the analysis of individual variables. Starting off from the list of missions tabulated in the Mission Table Creator, this worksheet creates tables with the mission names on the X-axis and the payload names for those missions on the Y-axis (ordered according to their instrument type), and displays one independent variable (Mass, Peak Power, Nominal Power or Data Volume) as the content. This will help by providing a useful tool for visual analysis and quick comparisons.

All that is explained above is automatic, and only requires minimal input from the user. More complex analyses can be performed rapidly by a clever use of these tools and the use of copy paste: for example, by changing the categories searched (e.g. different instrument categories) and copying the statistical tables of each search on a separate worksheet we can obtain a set of tables that provide a first step to compare different instruments.

VII.IV Views

As already indicated in Fig. 4, the database includes several prepared views, tables and diagrams which should help to better interpret the data and to draw conclusions more easily.

These views are kind of standard tables and diagrams which make use of the data prepared in the Mission-/Payload-/Mission-versus-Payload-creator sheets and to process them in a way that they are easy to understand and quickly used in an early design study:

So far, as presented in the lower part of Figure 4 , there is:

- ***Instrument-Analysis*** view, which contains mass, peak/nominal power, data volume and the respective correlation parameter for year-vs-mass, mass-vs-power, mas-vs-data and power-vs-data volume
- ***Mission-Analysis*** view; which is the equivalent of to the Instrument analysis but with mission related data
- ***Box-and-Whisker*** view, which is one of the graphical representations possible for the Instrument analysis
- ***Mission-vs-Payload*** view, which is basically an improved and grouped matrix of the Mission-vs-Payload creator, comparing (categorized) Payload parameter with a selected type of Missions.

Some of the outcomes and snapshots are presented in the following section.

VIII. PRELIMINARY FINDINGS

In addition to the databases and tools which have been presented in the previous sections, a preliminary analysis has been performed over the available data using the tools developed to that end, and this has provided a first positive impression as to the validity of the premise upon which this study is based – that there are relations to be found, and rules that can be derived from said relations to help in the preliminary design of a payload and therefore of a system. Below, different types of findings are described, including a first assessment as to whether this is already promising or needs more investigation and more data.

VIII.I Historical Evolutions

The current data availability does not allow yet for meaningful results related to the historical evolution of a certain instrument type. The idea is to derive either a performance increase and/or mass increase or decrease throughout the last decades, when comparing a payload family in itself. Candidates for such findings could be e.g. magnetometers, radiometers or certain detectors due to their rather similar design (within their categories).

VIII.II Global findings

At this point in time, through the use of the tools and information previously presented, already a couple of elements have been identified which provide some valid initial considerations for sizing an unknown payload.

Something as apparently trivial as having identified a mean number of instruments for typical exploration missions (6.5), and a fork which "limits" how many are normally included (between 3 and 12), provides a first idea for a payload preliminary design. This is specially so when combined with other limitations, such as the 20% maximum deviation from the typical values of mass and power which was seen when analysing all the payloads. This is based on the information gathered out of the Payload Table Creator and its automatic analysis of correlations, Pearson R coefficients and standard deviations.

As another example of rather global findings there is the Box-and-Whisker diagram which can be extracted out of the Instrument-Analysis-view.

Figure 5 shows an example of a compilation with instruments related to science missions, presenting their range, mean values and (25% +/-1) quartiles around that mean value. Based on the data incorporated at that time, it can be seen that the average nominal power consumption for imaging instruments is somewhat in the middle of its range whereas this is not the case for particle detectors, where the mean value is at the very lower edge of the overall range. Even considering a certain potential inaccuracy of the data, an impression of how to best estimate an undefined particle detector in this case is provided.

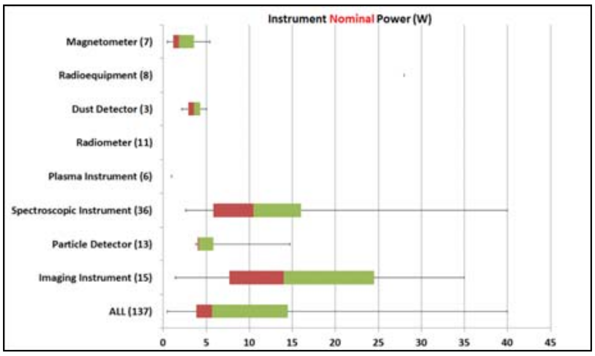

Fig. 5: Example of a Box & Whisker diagram extracted from the Payload-Table creator

For the next project phases, more and more detailed restrictors and rules are hoped to be found as the overall study, and hence the data gathering, continues.

VIII.III Specific findings

As for the historical evolutions, no real design-estimation-relationships for the impact of instruments selection and combinations on the system design have been established. The idea is to have sensitivities related to the size of certain instruments compared to e.g. performance and/or accuracy required, mission targets, operational orbits, distance to Earth or launch dates.

However, what can be extracted today is for instance a payload-type based comparison between pre-defined selections of mission types as can be seen in Table 2 below, which is a snapshot of the Mission-vs-Payload view. This example indicates that for the chosen missions the magnetometers selected are in the 4 kg-range, which seems to be a bit higher than for e.g. dust detectors or plasma instruments, which are in the 2-4 kg range. A particle detectors mass the other hand could vary between 0.5 and 15 kg, looking at the given data.

Instrument	Type	Mission						
		Advanced Composition Explorer	Ulysses	ExoplanetSat	Giotto	Herschel-Planck	Hipparcos	Mars Express
DUST (Dust Experiment)	Dust Detector		3,8					
DID (Metoroid Shield Momentum SensorImpact Plasma and Momentum Se	Dust Detector				2			
RTSW (Real Time Solar Wind)	Experiment	3,9						
GWE (Gravitational Wave Experiment)	Experiment		0					
OPE (Optical Probe Experiment)	Experiment				1,1			
MaRS (Radio Science Experiment)	Experiment							0
LEIT (low energy imaging telescopes)	Imaging Instrument			60				
HMC (Camera)	Imaging Instrument				11,48			
Schmidt Telescope	Imaging Instrument						210	
HRSC (Super/High-Resolution Stereo Colour Imager)	Imaging Instrument							19,6
THEMIS (Thermal Emission Imaging System)	Imaging Instrument							
MAG (Magnetometer)	Magnetometer	4,1						
FGM/VHM (Fluxgate Magnetometer/Vector Helium Magnetometer)	Magnetometer		4,7					
EPAM (Electon, Proton, and Alpha Monitor)	Particle Detector	12,8						
SWEPAM (Solar Wind Electon, Proton, and Alpha Monitor)	Particle Detector	6,8						
COSPIN (Cosmic-ray and Solar Particle Investigation)	Particle Detector		14,6					
EPAC/GAS (Energetic Particle Composition Experiment/Interstellar Neutral	Particle Detector		4,3					
HI-SCALE (Heliosphere Instrument for Spectra Composition and Anisotropy	Particle Detector		5,8					
EPA (Energetic Particles)	Particle Detector				0,5			
ASPERA (Energetic Neutral Atoms Analyzer)	Particle Detector							8,2
JEM-X (Joint European X-ray Monitor)	Planetary Radio Astronomy							
JPA (Fast Ion SensorImplanted Ion Sensor)	Plasma Instrument				4,08			
RPA (Electron Electrostatic AnalyserPositive Ion Cluster Composition Anal.)	Plasma Instrument				2,85			
MARSIS (Subsurface-Sounding Radar/Altimeter)	Radio equipment							17
ACRIM-III (Active Cavity Radiometer Irradiance Monitor-III)	Radiometer							
CRIS (Cosmic Ray Isotope Spectrometer)	Spectroscopic Instrument	31,6						
SIS (Solar Isotope Spectrometer)	Spectroscopic Instrument	22,4						
ULEIS (Ultra Low Energy Isotope Spectrometer)	Spectroscopic Instrument	21,9						
SEPICA (Solar Energetic Particle Ionic Charge Analyzer)	Spectroscopic Instrument	38,3						
SWIMS (Solar Wind Ion Mass Spectrometer)	Spectroscopic Instrument	8,6						
SWICS (Solar Wind Ionic Composition Spectrometer)	Spectroscopic Instrument	6						
GRB (Gamma-Ray Burst Experiment)	Spectroscopic Instrument		2					
SWICS (Solar Wind Ion Composition Spectrometer)	Spectroscopic Instrument		5,6					
SWOOPS (Solar Wind Observations Over the Poles of the Sun)	Spectroscopic Instrument		6,7					
URAP (Unified Radio and Plasma-Wave Experiment)	Spectroscopic Instrument		7,4					
NMS (M-analyser/E-analyser)	Spectroscopic Instrument				10,94			

Table 2: Snapshot of Mission-vs-Payload view matrix

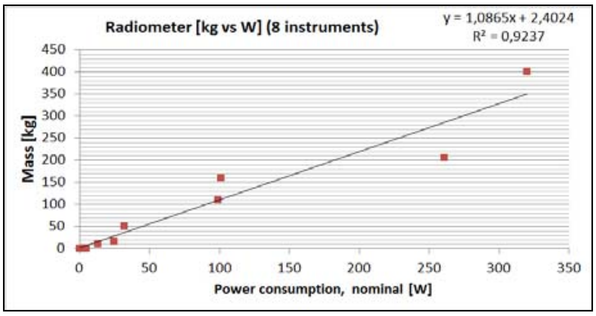

Fig. 6: Example of Mass-vs-Power for an instrument type (here: radiometer) providing an idea about extrapolation for these two main design parameters.

As another example of supporting information for payload selection- and system design processes in science mission proposals, charts such as presented in Figure 6 could help to extrapolate a particular payload size or to correlate a power consumption value to a mass value if one of them is still missing during the initial instrument definition.

IX. SUMMARY AND CONCLUSION

The presented work intends to support the science mission formulation process on different levels, including the provision of:

a. an instrument and mission catalogue,
b. Mission vs. P/L comparison matrices,
c. assessment functions for parameter (e.g. mass, power consumption) averages and ranges as system design drivers,
d. sensitivities/evolution of P/L-performance parameter variations based on mission targets, orbits, launch date (i.e. age),
e. identification of potential "default" model payload sets,
f. a preceding P/L-data set to be connected to the commonly used Space Mission Analysis and Design (SMAD) processes
g. and a rapid assessment scheme for system drivers based on mission goals/ objectives.

There are some ***limitations*** already apparent when using the data and the related workbook. For comparisons and evolutions, exploration and Earth orbiting missions seem to be the most promising. Astronomy and partially fundamental physic missions tend to have a very much customized space system, with the payload (e.g. Hubble telescope) being fully integrated in the bus. There is not such a clear split between payload segment and service segment due to unique instrumentation. This has led already in some views to too extreme data which has to be excluded for ranges and design factors. As an example, the INTEGRAL mission has a ~800kg imaging instrument whereas the usual imagers are in the 5-10 kg range.

On the other hand, the current (spreadsheet-based) tools have shown already some ***benefits***: Without deep knowledge of payload design, one could use instantly the "extension" of the information set which is for example provided by ESA for their mission calls (see Table 1 again) to extract preliminary mass and power data for the system budget estimates.

Graphs and sensitivity charts allow for improved extrapolation of such data if the desired historical numbers are not available.

Box and Whisker diagrams provide good indications of how a mean value has to be interpreted as part of the overall range (for e.g. the average mass of a certain instrument type).

X. OUTLOOK

The future steps to evolve the current state of the overall study will go through further data gathering and editing, so as to continue to complete and develop the current database.

As the database grows, the current tools shall be upgraded in order to be able to envelope that information. The current state of the tools is able to handle a good number of new instruments and missions, in any case, and they have been designed to be easily upgradeable.

With a growing wealth of information, more detailed analyses can be undertaken, and with greater focus in specific relevant parameters. For example, analysis of missions and instruments by targets should prove to be an interesting case, especially when crossing the results of different cases (e.g. compare an analysis done for missions and instruments for Venus exploration and another for Mars exploration). These detailed analyses should be able to provide increasing levels of reliability to those considerations and rules that should be unearthed.

The final and most interesting step will be the creation of rapid analysis tools which will take full advantage of these rules and which can be directly used in the preliminary design of future missions.

Using design-estimation-relationships (comparable with the parametric approach for cost analyses, using cost estimation relationships, CER's) related to mission- and payload based design drivers should improve the initial assessments especially for science missions, dealing with a more complex set of instruments than small Earth Observation satellites for instance.

However, in order to improve the full chain of mission definition processes, a lot of effort still has to be spent on the tracing of mission goals, objectives and the subsequent derivation of measurement and payload performance requirements, which – on the other hand – influences the (technical) selection processes of instruments and their combinations itself.

XI. REFERENCES

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