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SPACE MISSION ARCHITECTURE TRADE OFF BASED ON STAKEHOLDER VALUE

Key words*: Space mission architecture; trade-off; value; stakeholder; decision*

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Introduction

Most of the major system decisions are made during the early phases of the project. Part of this work is done during the space mission architecture trade off.

Traditionally, the main objective of space mission architecture trade offs is to meet high performance requirements on a cost-time effective way with low level of risk.

However, stakeholders may value performance, cost, risk and schedule attributes differently.

Introduction

Space mission development requires a high level of sustainability that only can be given by stakeholders who provide financial, political, and economic support.

Sustainability here refers to the fact that stakeholders will be assured to receive the required amount of value over a specified period of time.

In this way, early stage design provides the greatest opportunity to explore design alternatives and perform trade studies to get stakeholder satisfaction.

Introduction

So, the main goal is to identify concepts in a trade off process at an early design phase from a new paradigm: a evaluation of the architecture solution effectiveness through the value that the stakeholder gives to performance, cost, risk, and schedule attributes.

Affordability

Sustainability

Concept Exploration and Systems Engineering

Project planning for space products is usually structured into sequential phases.

The initial design activity performed by "Advanced Projects" teams consists of inventing, creating, concocting and/or devising a broad spectrum of ideas and alternatives for missions where new projects (programs) could be selected from.

Traditionally at the beginning, trade studies start with an assessment of how well each of the design alternatives meets the system effectiveness (performance, cost, schedule, and risk attributes).

Concept Exploration and Systems Engineering

On the other hand, the objective of systems engineering is to derive, develop and verify a life cycle balanced solution that satisfy stakeholders requirements [evolved from 2].

Thus, design trade studies become an important part of the systems engineering process.

The ability to perform these studies is enhanced by the development of system models that relate the decision drivers to those assessments i. e. trade the importance stakeholders give to performance, cost, risk and schedule attributes rather than those attributes themselves.

Integrated Space Mission Architecture Trade off

Considering that about 80% of the life cycle cost, performance, risk and schedule attributes of a system are committed by decisions made during design concept exploration; this paper addresses several questions such as:

- How to improve such decisions?
- How to evaluate system architecture through how much stakeholders value cost, performance, risk and schedule system attributes?
- How to anticipate such evaluation to the beginning of design process?

These questions do reflect the state of art of the design trade off process regarding to phase A “advanced studies”.

Integrated Space Mission Architecture Trade off

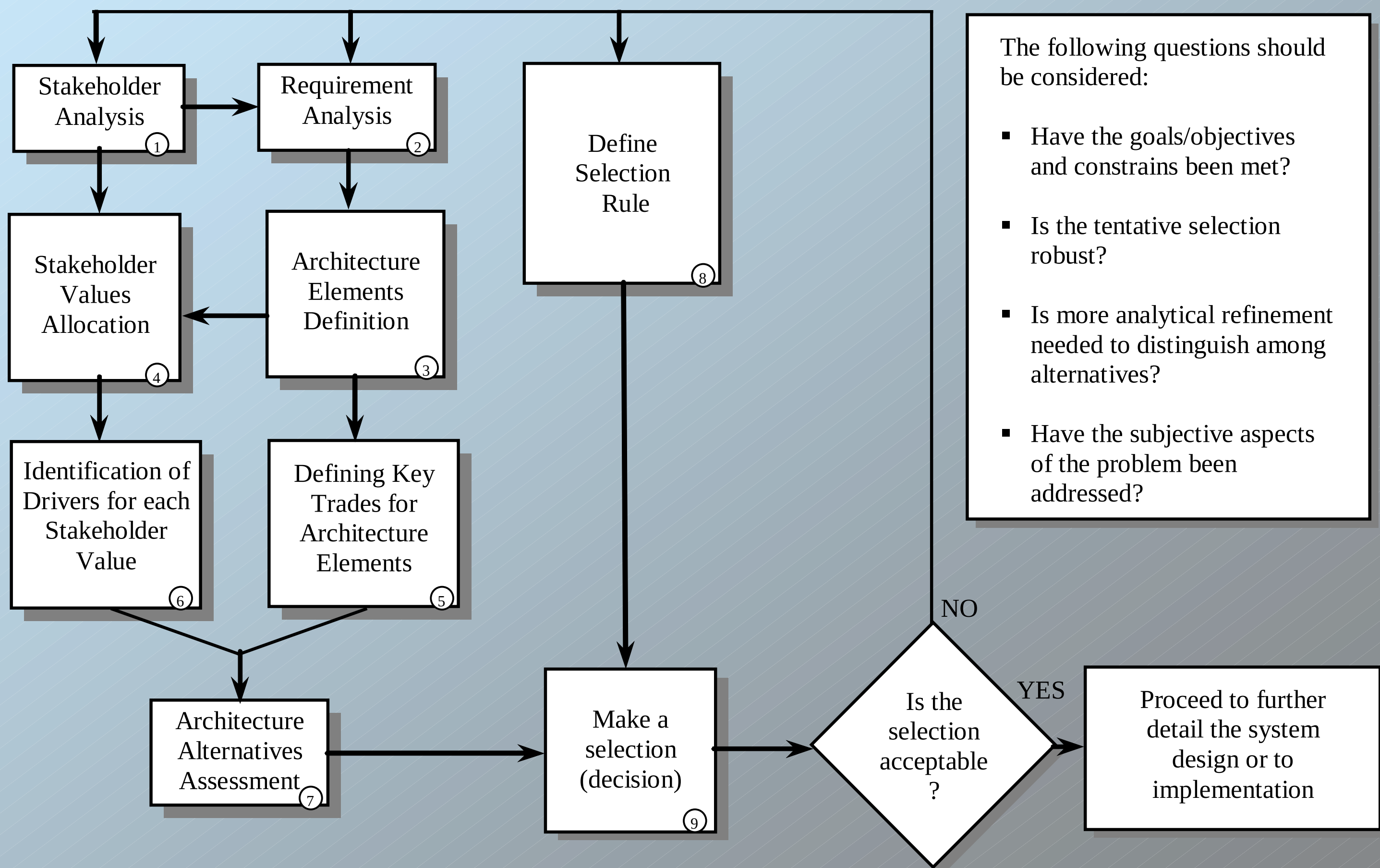
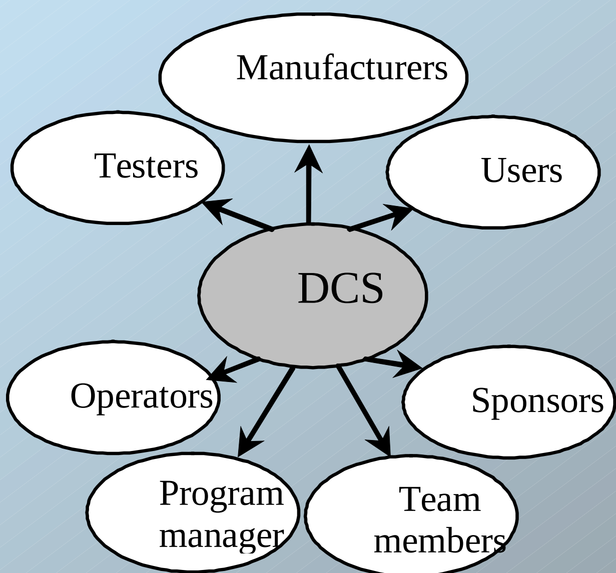


Figure 1 - Integrated space mission architecture trade off process

Stakeholder and Requirement Analysis

The first step is to identify project stakeholders.

The second step of the method is to identify the stakeholders' interests and the relative importance for each one.



Stakeholder (score)	**Interests (value attributes)**	
	Performance	**Cost**
User	Availability (5%)	Maintenance (5%)
Sponsor	Sustainability (10%)	Elements (70%)
Program manager	Responsiveness (3%) …	Development Process (5%)
⋮	(10%)	(10%)
Operators	Operation easiness (10%)	Operation (5%)
Total	100%	100%

Figure 2 - Stakeholder context diagram and interests for Data Collection System (DCS)

Architecture Elements Definition, Key Trades Options, and Decision Drivers for each Stakeholder Value

Table 1 - Architecture elements and alternative options for a Generic Mission

Mission Segment	Architecture Elements	Alternative Options
Segment 1	Element 1	Alternative 1
		Alternative 2
		Alternative 3
	Element 2	Alternative 1
		Alternative 2
Segment 2	Element 3	Alternative 1 ⋮
	Element 4	⋮
	Element 5	⋮
Segment 3	⋮	
⋮		

Architecture deals with elements, which compose the system concept, capture and reflect the key desired value attributes (effectiveness) of the solution under elaboration.

Table 2 - Decision drivers identification for a Generic Mission

Architecture elements	Element alternatives	Cost decision drivers	Performance decision drivers
Element 1	Alternative 1	Decision driver 1 (%C)	Decision driver 1 (%P)
		Decision driver 2 (%C)	Decision driver 2 (%P)
		Decision driver 3 (%C)	
	Alternative 2	Decision driver 4 (%C)	Decision driver 3 (%P)
		Decision driver 5 (%C)	Decision driver 4 (%P)
	Alternative 3	Decision driver 6 (%C)	Decision driver 5 (%P)
Element 2	Alternative 1	Decision driver 7 (%C)	Decision driver 6 (%P)
	Alternative 2	Decision driver 8 (%C)	Decision driver 7 (%P)
Element 3	Alternative 1	Decision driver 9 (%C)	Decision driver 8 (%P)
		Decision driver 10 (%C)	Decision driver 9 (%P)
⋮	⋮	⋮	⋮
		100 % ~ 80 % of total cost	100 % ~ 80 % of total perfor.

The effectiveness model can be built through decision drivers which constitute the main mission parameters or characteristics that influence such attributes. These characteristics are the ones that the stakeholder or designer can trade off.

Architecture Elements Definition, Key Trades Options, and Decision Drivers for each Stakeholder Value

Table 3 - Relationships among architecture elements options, stakeholder value attributes and cost, performance drivers associated with (DCS)

Architecture Elements and Key trades options		**Stakeholder value attributes (interests)**	**Decision drivers**
Mission	Space processing x ground processing	Maintenance price	Processing (cost)
		Operation price	Mission operators (cost)
		Availability	Time of transmit (performance) Message size (performance)
	Level of autonomy	Maintenance price	Infrastructure (cost)
		Operation price	Control operators (cost) N° of control stations (cost)
		Operation easiness	N of manoeuvres (performance)
Orbit / Constellation	Number of spacecrafts and orbit plans	Maintenance price	Infrastructure (cost)
		Operation price	Control operators (cost)
		Elements price (+1)	N° of spacecrafts (cost) N° of ground stations (cost) N° of control stations (cost)
		Availability	N° of spacecrafts (cost) Revisit time (performance) Interval of collect (performance) Interval of transmit (performance)
		Operation easiness	N° of spacecrafts (cost) N° of manoeuvres (performance)
		Sustainability	Funding constrains (performance)
Payload	BER / Mass	Element price	Payload mass (cost)
		Develop. process price	N° of employees (cost)
		Availability	Data rate (performance)
⋮		⋮	⋮

Mission Architecture Alternatives Assessment

Table shows how to transfer the stakeholder analysis results (interests and importance from "Fig. 1") to the attributes modeled through decision drivers (from "Tab. 2"). "Table 4" results are the attribute value weights to stakeholder.

Table 4 - Definition of the attribute value weight to stakeholders

Decision drivers (cost)	**Associated stakeholder values (cost)**	**W *C=AVC**	**AVW to stakeholder (%) AVC / Sum total AVC**
Decision driver 5 (4% of C)	Interest 1 (5% of W)	20	%
Decision driver 6 (3% of C)	Interest 2 (10% of W)	30	%
⋮	⋮	⋮	⋮
		Sum total AVC	**Total 100%**

Mission Architecture Alternatives Assessment

By this way, it is possible to translate the stakeholder value preferences towards cost, risk, schedule and performance attributes inside the space mission architecture trade off process.

Table 5 - Definition of the attribute value weight to stakeholders for DCS

Stakeholder values Fig. 1 (cost)	**Decision drivers from Table 1 (cost)**
Maintenance (10%)	Processing (3%) Infrastructure (7%)
Elements (70%)	N° of spacecrafts (?) N° gr. stations (5%) N° contr. stations (5%) Payload mass (20%) Bus mass (30%) Launch (10%)
Dev. process (5%)	N° of employees (5%)
⋮	
Operation (5%)	Operators (5%)
Total 100%	**Total 100%**

Stakeholder values Fig 1 (performance)	**Decision drivers from Table 1 (performance)**
Sustainability (30%)	Funding constrains (30%)
Availability (40%)	Time of transmit (5%) Message size (5%) Revisit time (10%) Interval of collect (5%) Interval of transmit (5%) Data rate (10%)
⋮	
Oper. easiness (10%)	N° of maneuvers (10%)
Total 100%	**Total 100%**

Mission Architecture Alternatives Assessment

Example for Data Collection System

From Table 4

Attribute value weight to stakeholder

From Table 2

Architecture elements		Alternative options	Processing (cost)	Infrastructure	N° of ground stations	N° of control stations	N° of spacecrafts (cost)	Payload mass (cost)	Bus mass (cost)	Launch (cost)	N° of employees (cost)	Operators (cost)	Funding constrains (perf.)	Time of transmit (perf.)	Message size (perf.)	Revisit time (perf.)	Interval of collect (perf.)	Interval of transmit (perf.)	Data rate (perf.)	N° of maneuvers (perf.)	Element stakeholder satisfaction (cost)	Element stakeholder satisfaction (performance)
Attribute value weight to stakeholder			3	7	5	5		20	30	5	5	5	30	5	5	10	5	5	10	10		
Mission	Processing	Space proces.	9									7		7	8						62	75
		Some level	4									5		5	5						37	50
		Ground proces.	1									3		3	2						18	25
	Autonomy	Low level		8		5														1	81	10
		Medium level		5		3														5	50	50
		High level		2		1														7	19	70
Orbit / constellation	Constellat.	1 spacecraft																				
		2 spacecraft																				
		4 spac. 2 plans																				
		8 spac 3 plans																				
	Altitude	LEO																				
		MEO																				
		GEO																				
		⋮																				

Element impact on architecture taking into account decision driver

10 very high (cost or perf. increase)
1 very small

Stakeholder satisfaction with architecture:
Archit. 1 (cost) = 62 (space processing) + 81 (low level autonomy) + …
(perf.) = 75 (space processing) + 10 (low level autonomy) + …
Archit. 2 (cost) = 37 (some level) + 81 (low level autonomy) + …
(perf.) = 50 (some level) + 50 (low level autonomy) + …

Figure 3 - Stakeholder value trade off matrix

Selection Rule Definition and Make a Selection

The expected result from the integrated space mission architecture trade off process is to obtain a graph as shown in Figure 4

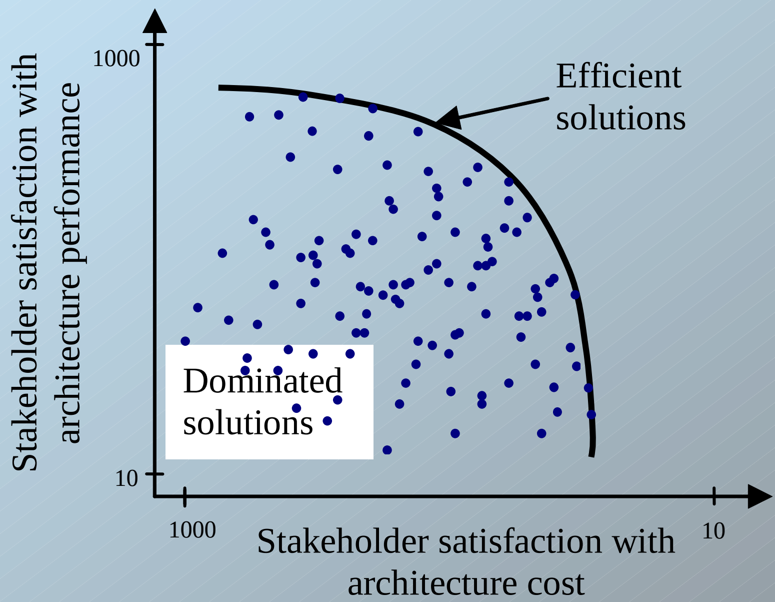


Figure 4 - Concept exploration flow (Larson, and Wertz, eds. 2003).

Designs represented by points on the envelope are called stakeholder satisfaction effective (efficient or non-dominated) solutions.

Conclusions

The proposal presented in this paper provides a means for innovating the mission design process by interconnecting stakeholder needs, requirement analysis, concept exploration and decision drivers in order to capture in the trade off process the value given by stakeholders to the architecture performance, cost, risk and schedule.

Thus, the paper proposes a subtle but closer to reality paradigm shift: trade the importance stakeholders give to performance, cost, risk and schedule attributes rather than those attributes themselves.

Thank you!

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