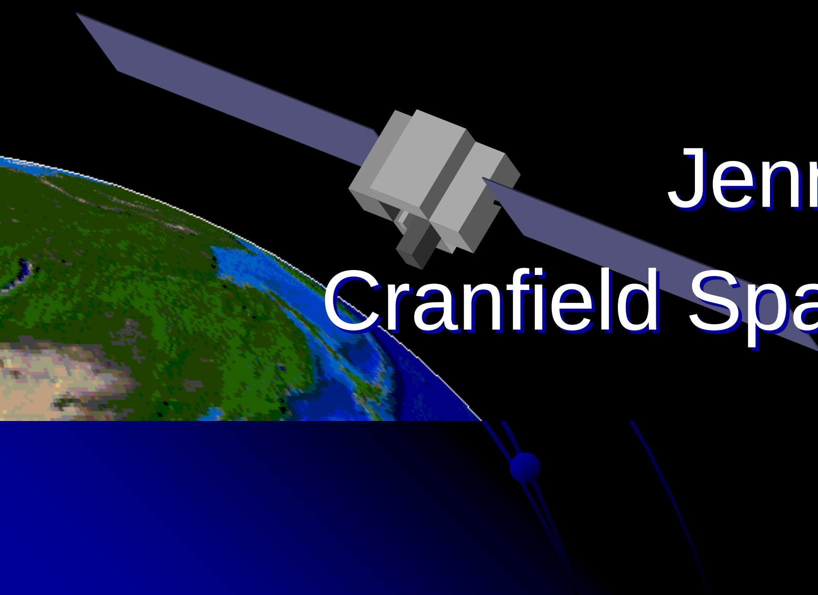
Modular Architecture & Product Platform Concepts Applied to Multipurpose Small Spacecraft



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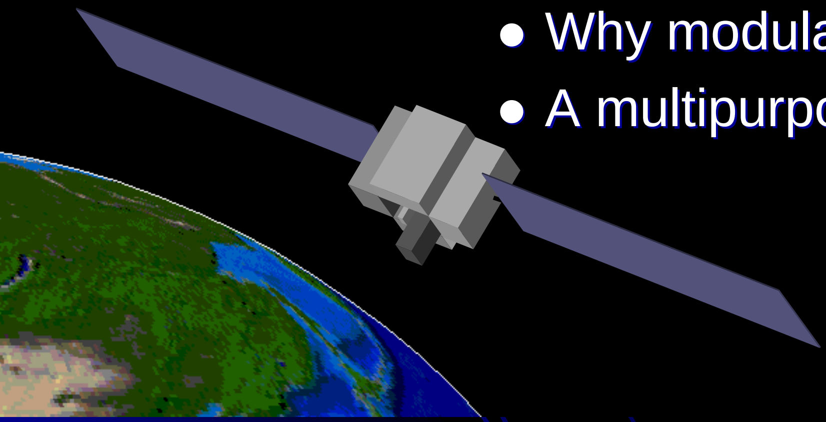
Introduction

This presentation will introduce the concept of product platforms to enable modular architecture, and then apply it to the case of multipurpose small spacecraft

- Why multipurpose small spacecraft
- Why modularity & product platforms
- A multipurpose smallsat as a product platform

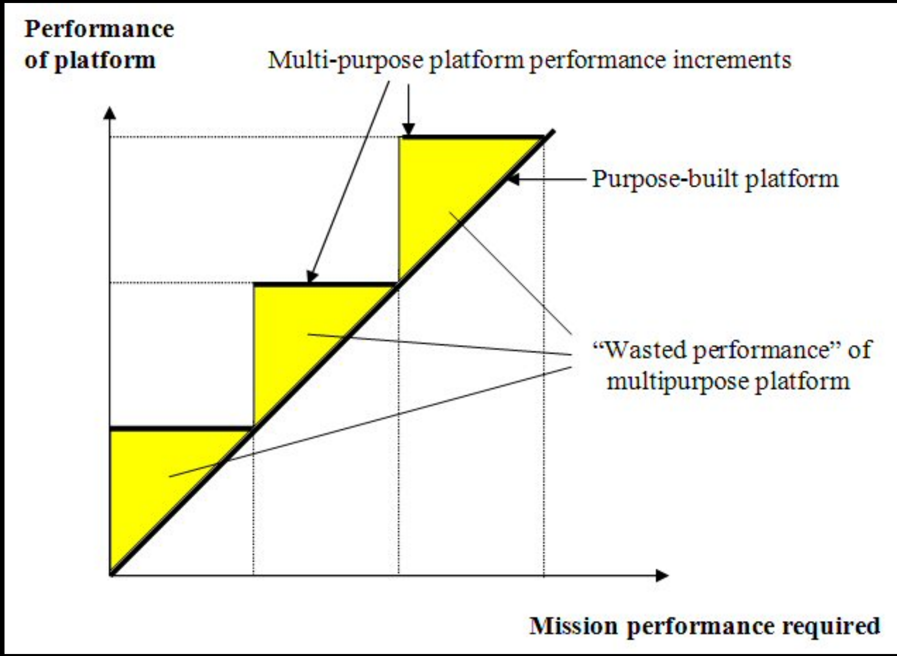


Multipurpose S/C Platforms

- Missions based on multi-purpose smallsat platforms have a number of advantages:
  - Time to flight – design around existing platform reduces Phase A/B workload, makes use of existing supply chain infrastructure, established knowledge base of team
  - Cost – likely to obtain higher performance for given cost, as R&D outlay spread over multiple missions
  - Risk – reduced risk by using proven designs and processes
- But, there are also drawbacks…

Multipurpose Platforms – The Drawbacks

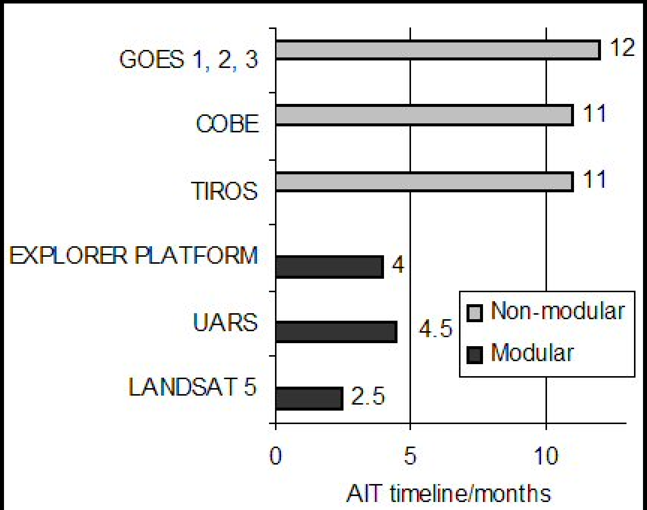
- Resulting S/C unlikely to be as good a "fit" to mission specification as bespoke design
- If the multipurpose platform requires too much customisation, the benefits are lost
- Risk of "wasted performance" where standard platform models are used:



Use of Modularity

Modularity may be used to mitigate the identified drawbacks, and to enhance the benefits:

- System upgrading – modularity can ease the upgrade process, and reduce the performance increments in the products offered (reducing wasted performance)
- Integration & testing – increase concurrency in the AIT process, & use standard, simple interfaces between modules to further reduce time-to-flight



e.g. see comparison of AIT timelines for modular vs non-modular GSFC spacecraft…

Product Platforms – A Framework for Modularity

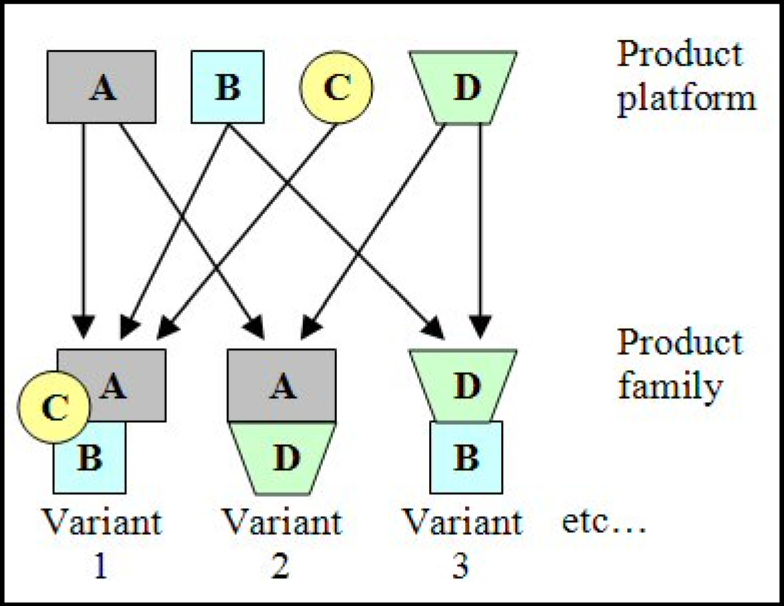
"A set of subsystems & interfaces developed to form a common structure from which a stream of derivative products is derived"*

- Strategy now in common use in electronics, automotive and consumer electrical industries
- Useful in environments where multiple, related products are offered

*Meyer, 1997

Product Platform & Product Family

- The platform is the set from which a family of different, but related, products can be produced:



Benefits of Product Platform Strategy

- In the automotive industry, Volkswagen-Audi Group produces a family of 19 vehicles based on its VW A-platform:

Audi TT

Skoda Octavia

VW Golf

Savings made through use of product platforms are estimated by VW at $1.5bn per year

Application of Product Platforms in the Space Sector

- Product platform theory evolved within the mass-customisation industries
  - Characterised by high volumes and (relatively) low unit costs
- Spacecraft manufacture is characterised by very low volumes, and very high unit costs
- However, product platform concepts have been applied in the architecture of interplanetary missions (JPL) and spacecraft communications subsystems (AeroAstro)
- The key to space application is the modular architecture at the heart of product platforms

Application to Multipurpose Smallsats

1. Identify possible mission types that may use multipurpose smallsat platform
2. Characterise identified mission types in terms of required functions
3. Define the product family – what missions fall within or outside platform scope
4. Define modules to comprise the product platform
5. Define variants, and relate to particular mission requirements

Identifying Mission Types

- Identify smallsat missions, & group into types by characterisation of typical functional requirements:

GEO comms
Microgravity
Space Physics
LEO comms
Technology
Astronomy
Interplanetary
Earth Observation

- Each of these mission types can be thought of as a potential variant in the spacecraft product family
- Actual product family is likely to be a subset of these

Characterising Mission Types

Mission types were characterised by reference to the following parameters:

- Physical accommodation of payload(s) – no., size, geometry, mass, field of view
- Communications & data handling – data rates, storage, operations, processing
- Attitude – pointing & stabilisation type, accuracy, stability, manoeuvrability
- Orbit – type, maintenance requirement, position knowledge
- Power – mean & peak levels, duty cycles
- Environmental – thermal, radiation, cleanliness etc

Variant-Function Matrix

- This identifies the required functions for each variant:

Variants	Functions																												
	Attitude Determination					Attitude Control					Propulsion				Power				Data Handling			Comms			Structures & Mechanisms				
	Earth sensing	Sun sensing	Inertial referencing	Star sensing	Magnetic field measurement	Reaction control	Momentum bias	Spin stabilisation	Magnetic torque	Gas thrusters	Kick motor(s)	Hydrazine	Electric	Other †	Electrical power storage	Solar energy conversion	Power control	Radioisotope power generation	S/C data processing	P/L data processing	Data storage	S-Band	X-Band	TDRSS	Primary structural support	Solar array drive	Mechanical deployment	Extend boom structures	Re-entry/ retrieval
Astronomy		X	X	X		X	X		X	X	X				X	X	X		X	X	X		X	X	X		X		
Space physics	X	X			X			X		X					X	X	X		X		X	X			X		X	X	
Interplanetary		X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X
Microgravity	X	X	X			X			X						X	X	X		X		X	X	X	X	X		X		X
Earth Observation	X	X		X	X	X	X		X	X		X			X	X	X		X	X	X	X	X	X	X	X	X		
LEO Comms	X	X			X	X	X		X	X		X			X	X	X		X		X	X			X	X			
GEO Comms	X	X				X	X			X	X	X	X		X	X	X		X		X	X			X	X	X		

†e.g. solar sailing

Defining the Product Family

- In the ideal case, a multipurpose S/C may be designed around a product platform that gives a variant for any mission type
- In reality, we see “sparse functions” in the variant-function matrix e.g. re-entry provision, RTG power
- These functions would dilute the product platform with seldom-used modules
- Modules that are unique to a product, and have a key impact on the final product, have been described as *form defining modules* *
- For spacecraft, a major form-defining module is the payload…

*Chandrasekaran, 2004

Defining the Product Family

- The XMM payload: a form defining module…

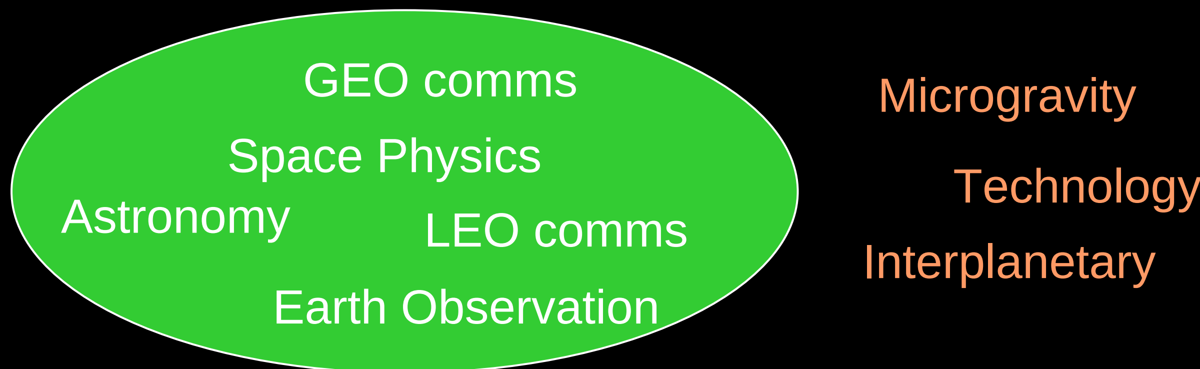
Defining the Product Family

- It is clear that products as complex as spacecraft cannot be entirely formed from a standardised set of modules
- To define a suitable scope for the product platform, we must strike a balance of:

Maximising range of applicable missions	Minimising occurrence of form-defining modules

Defining the Product Family & The Product Platform Modules

- Examination of clustering of functional requirement types suggests that the product platform should provide variants supporting this mission set:



- Modules showing highest frequency of occurrence in the product-variant matrix are chosen to form the product platform
- Specific requirements for the modules are quantified by allocating “capability increments”, based on the parameters of past & current missions

Modules & Variants

- A variant-module matrix can be defined - indicating variants suitable for different mission types, and their constituent modules:

Product Platform Modules ↓ / Product Family Variants →	Astronomy	Space physics	Earth Observation	LEO Comms	GEO Comms
Structural Modules (number of modules used indicated)	4	3	4	4	4
Basic Attitude Control Module (small wheels, magnetorquers)				X	X
Enhanced Attitude Control Module (large wheels, magnetorquers)	X		X		
Basic Attitude Determination Module (Earth sensor, magnetometer, sun sensors)		X	X	X	X
High accuracy Attitude Determination Module (Star tracker, IRU, sun sensors)	X				
Cold gas Propulsion Module	X	X			
Hydrazine Propulsion Module			X		X
Kick motor		X			X
Data Handling Module	X	X	X	X	X
Payload Data Handling Module			X		
Mass Memory Module	X	X			
S-Band Comms Module	X	X	X	X	X
X-Band Comms Module	X				
TDRSS Comms Module			X		
Battery Module (number of modules used indicated)	2	1	4	4	5
Power Control & Distribution Module	X	X	X	X	X
Body-mounted Solar Array Module		X			
Deployed-fixed Solar Array Module	X				
Deployed-articulated Solar Array Module			X	X	X

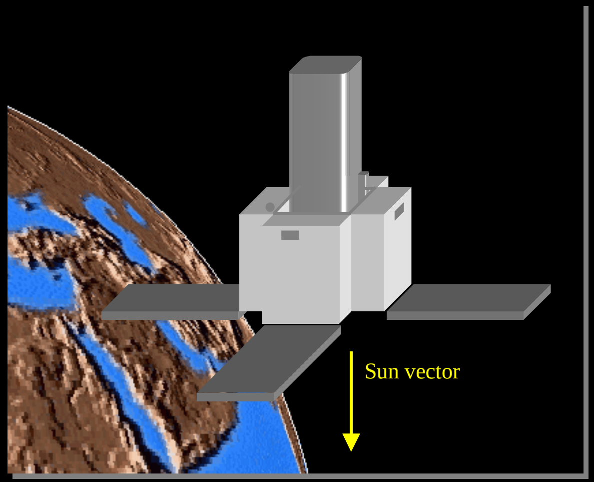
Example – Selecting a Variant

- X-ray astronomy mission used for selection of a suitable variant
- Mission parameters derived from HESSI & XTE missions
  - Payload mass 120kg, power 110W
  - Payload size 1.4m x 0.45m diameter
  - 25 arcsec pointing accuracy
  - 0.1° per sec manoeuvres
  - 10Gbits data rate over 10 min observation period
  - Inertial attitude
- Platform modules are selected to satisfy mission requirements…

Variant Selection

Key choices in selecting a suitable variant:

- Structural module configuration of 4 modules accommodates large payload instrument
- X-band comms module supports high downlink rate, S-band module for backup & TT&C
- Additional mass-memory modules provide necessary data storage
- High-accuracy attitude determination module, with enhanced attitude control module to provide necessary pointing accuracy and stability.
- High manoeuvrability provided by cold-gas propulsion module



Summary

- Product platform approach allows reduced programmatic costs and schedules
- It requires greater investment and manpower to implement, but this can be recouped in subsequent projects
- This high initial investment means it is not suitable for all suppliers
- However, the product platform approach is applicable at many levels of the spacecraft (component, subsystem, system), & may be implemented by adaptation of existing products
- It may also provide a framework for cooperation within the supply-chain