Employ. Deploy. Develop.

Assured Space Power Focused on Timely Satisfaction of Joint Force Commanders' Needs

OPERATIONALLY RESPONSIVE SPACE (ORS)

~~WHY~~ HOW ORS – Modular Space Vehicle on the T2E Mission

June 21, 2011

ALIBI → Why ORS this way . . .

- **Text Pole**

Yes = *5551

No = *5552

ALIBI → Why ORS this way . . .

- **Text Pole**

  Yes = *5551 **No = *5552**

- **Questions**
  - **How many people think we are launching all the satellites we need to in order to satisfy our operational, commercial, and scientific needs?**

ALIBI → Why ORS this way . . .

- Questions
  - How many people think we are launching all the satellites we need to in order to satisfy our operational, commercial, and scientific needs?
  - How many people think cost and schedule are a major contributing factor for that?
  - How many people in this room have a satellite or would like to have a satellite to launch, but can't because there aren't enough resources to go around?

Evolution of the Small Operational Satellite

TacSat-1 →

TacSat-2 →

TacSat-3 →

TacSat-4 →

ORS-1

Evolution of the Small Operational Satellite

TacSat-1 →

??

TacSat-2 →

$61M
(PM)

TacSat-3 →

$90M
(Wiki)

TacSat-4 →

$118M +
Grnd/Ops
(Wiki)

ORS-1

$226M
(Spaceflight Now)

Formula for Cost Overruns and Schedule Delays

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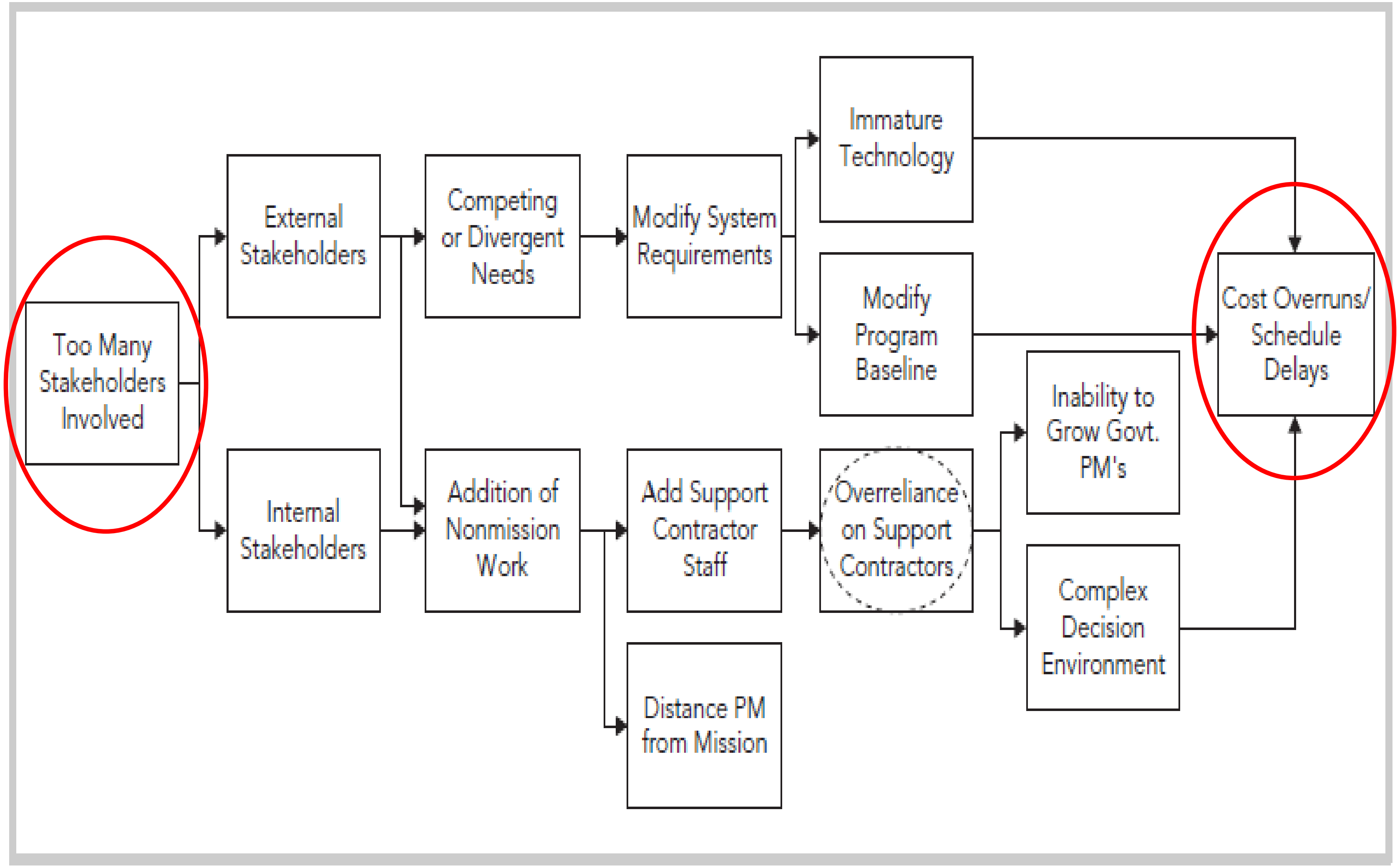

Cost Growth Due to Requirements Changes

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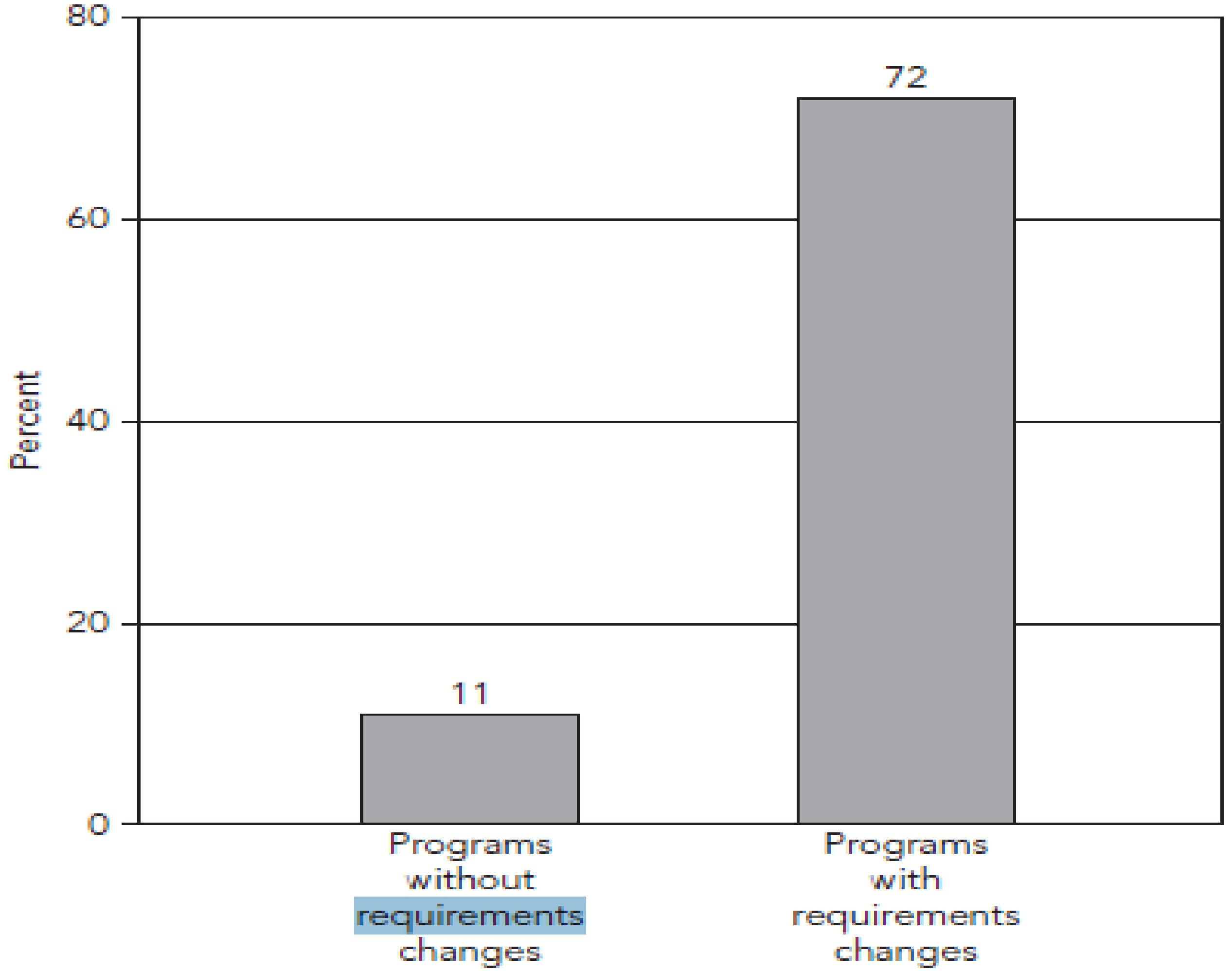

Moral of the Story

- **Set the pricepoint low enough to embrace – 1 customer = 1 spacecraft**
- **Put the standard bus to bed and embrace change**
  - **If things are going to change, make your architecture changeable (i.e., Modular + Scalable + Rapidly Configurable) . . . with minimal NRE**

ORS MOSA

How ORS

Develop through implementation + **Operational Context** = **T2E**

1. Demonstrate an end-to-end RRSW Tier-2 Response.
2. Develop a standards based, modular, rapidly configurable, multi-mission bus architecture.
3. Develop an operationally relevant radar capability.
4. Develop a rapidly configurable, multi-mission RF payload architecture.

Multi-Mission (MM) Specification

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Technical Requirements

- **Defined reference missions; developed technical specs**
  - **Begin with partially completed ORS mission kit chart**
  - **Choose appropriate missions for bus and payload based on maximum diversity**
    - Eliminated GEO – too much for this step
  - **Filled in rest of technical specs**
  - **Stretched some specs to eliminate homogeneous requirement – forced spread**
- **Mission Chart shows final specs**
  - **Chart is part of T2E Mission Spec by original reference, will enter through CCB**

	LEO SAR	LEO TES	LEO EO/IR	LEO HSI	LEO SSA	UHF Comm	EHF (Tactical Protected Comm)
Applies to:	Bus & PL	Bus & PL	Bus	Bus	Bus	Bus & PL	Payload
Heritage	T2E	T2E	ORS-1	TacSat-3	SIV / SAPPHIRE	TacSat-4	EPS
Requirements Documented	GRD	Classified	CDR	CDR	SIV TRD	CDR	
Source	T2E Program	NRO	ORS-1 Program	AFRL	SIV Users Guide / SAPPHIRE TTRDP	NRL	
GRMC	T2E	TES	ORS-1	TacSat-3	TBD	TacSat-4	

MM Specification

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ORS Multi-Mission Key Parameters Matrix

		ISET LEO Ref	LEO SAR	LEO TES	LEO EO/IR	LEO HSI	LEO SSA	ISET HEO Ref	UHF Comm	EHF (Tactical Protected Comm)
			Bus & PL	Bus & PL	Bus	Bus	Bus		Bus & PL	Payload
Prov-enhance	Heritage	N/A	T2E	T2E	ORS-1	TacSat-3	SIV / SAPPHIRE		TacSat-4	EPS
	Requirements Documented	GBS / PDG v3.2	GRD	Classified	CDR	CDR	SIV TRD	GBS / PDG v3.2	CDR	
	Source	NRL / ISET	T2E Program	NRO	ORS-1 Program	AFRL	SIV Users Guide & SAPPHIRE TTRDP	NRL/ISET	NRL	
	GRMC		T2E	TES	ORS-1	TacSat-3	TBD	NA	TacSat-4	
Orbit	Type	Circular	Circular	Circular	Circular	Circular	Equatorial	Low HEO	Low HEO	Low HEO
	Altitude (km)	350-705	480-520	480-520	350 - 450	400 - 600	705	750/12050	750/12050	750/12050
	Inclination (deg)	0-98	40-55	25 - 35	40 - 55	Sun Sync 98	0	63.4	63.4	63.4
PL	Total Mass (kg)	< 175	<150	150	< 175	< 175	100	< 175	< 175	< 175
	Peak Power (W)	700	1200 for 10 mins every orbit	500 for 20 mins every orbit	1000 for 10 mins every orbit	600 for 10 mins every orbit	100	700	624	510.0
	OAP (BOL/EOL W)	400	> 150	400	475	340	> 100	200	350	338
	Data Storage (Gb)	> 1	50	25	64	200	16	> 1	> 1	> 1
SV Mission	Mission Availability (constrained to time on target over AOI performing mission ops)		99%	99%	99%	99%	99%		99%	99%
SV Design Rqmnts	Design Life (months)	12-18	12-18	12-18	12-18	12-18	12-18	12-18	12-18	12-18
	S/C Class	C/D	C/D	C/D	C/D	C/D	C	C/D	C/D	C/D
	Classification		Secret	TS/SCI	Secret	Secret	Unclass		Unclass	Class
	TT&C		SGLS	TDRSS	SGLS	Dual-Band	TDRSS		NA	NA
	Design Reliability	0.85	0.85	0.85	0.85	0.85	0.85		0.85	0.85
	Standards	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS	SPA-Compliant HWCIs Drive WBS
	Mission Conops		T2E	TS-1	ORS-1	TS-3	SAPPHIRE		TS-4	Polar AEHF
	Mission DwnLnk Waveform / DwnLnk Rate		CDL Ka / 600	TDRSS	CDL Ka / 600	CDL Ka / 600	TDRSS		(UHF/X) / (10-40/0.5-2)	EHF
	Deployable Mechanisms	Mission Choice	SA, RF Antenna	SA	SA	SA	SA	Mission Choice	RF Antenna, Radiator	RF Antenna, Radiator
	ADCS Stabilization Type	3 -axis	3-axis	3-Axis	3-axis	3-axis	3-axis	3 -axis	3-Axis	3-Axis
	ADCS Pointing Knowledge (deg) (3-sigma)	0.0167	0.01670	0.00423	0.00130	0.01300	0.03	0.01	0.20	0.20
	ADCS Pointing Control (deg) 3 (sigma)	0.05	0.033	0.050	0.005	0.065	0.10	0.05	0.20	0.20
	Stability (asec/sec)	5	3.200	5	0.020	0.020	2	5	5.0	5.0
	Slew Rate (deg/s)	0 < x < 2	≥ 2	< 2	≥ 2	≥ 2	0.150	0 < x < 1	0.035	0.035
	Acceleration (deg/s^2)		≥ 0.07	0.030	≥ 0.03	0.070	0.030		0.030	0.030
	Position Knowledge m (3 Sigma)	90	90	< 25	90	90	< 25	90	90	90
	Propellant Type & Class	hydrazine monoprop (TDM)	NA	non-toxic (TDM)	hydrazine monoprop (TDM)	non-toxic (TDM)	non-toxic (TDM)	hydrazine monoprop (TDM)	hydrazine monoprop (TDM)	hydrazine monoprop (TDM)
FSW	Arch Approach - SW & Data-Centric Designs MOSA-Compliant & SPA-Compliant		ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS	ORS FSW Arch Guide CIs Drive WBS
	Software / Firmware		SW-CSCI FW-CSCI	SW-CSCI FW-CSCI	SW-CSCI FW-CSCI	SW-CSCI FW-CSCI	SW-CSCI FW-CSCI		SW-CSCI FW-CSCI	SW-CSCI FW-CSCI
	On-Orbit Image/Product Processing		No	Yes	No	No	Yes		Yes	Yes
	Complexity of SW Apps		Med	High	Med	High	Med		High	High
LV	Type	Minotaur I/IV	Minotaur 1	Minotaur I	Minotaur I	Minotaur I	EELV/ESPA	Minotaur IV	Minotaur IV	Minotaur IV

T2E Deployed Configuration

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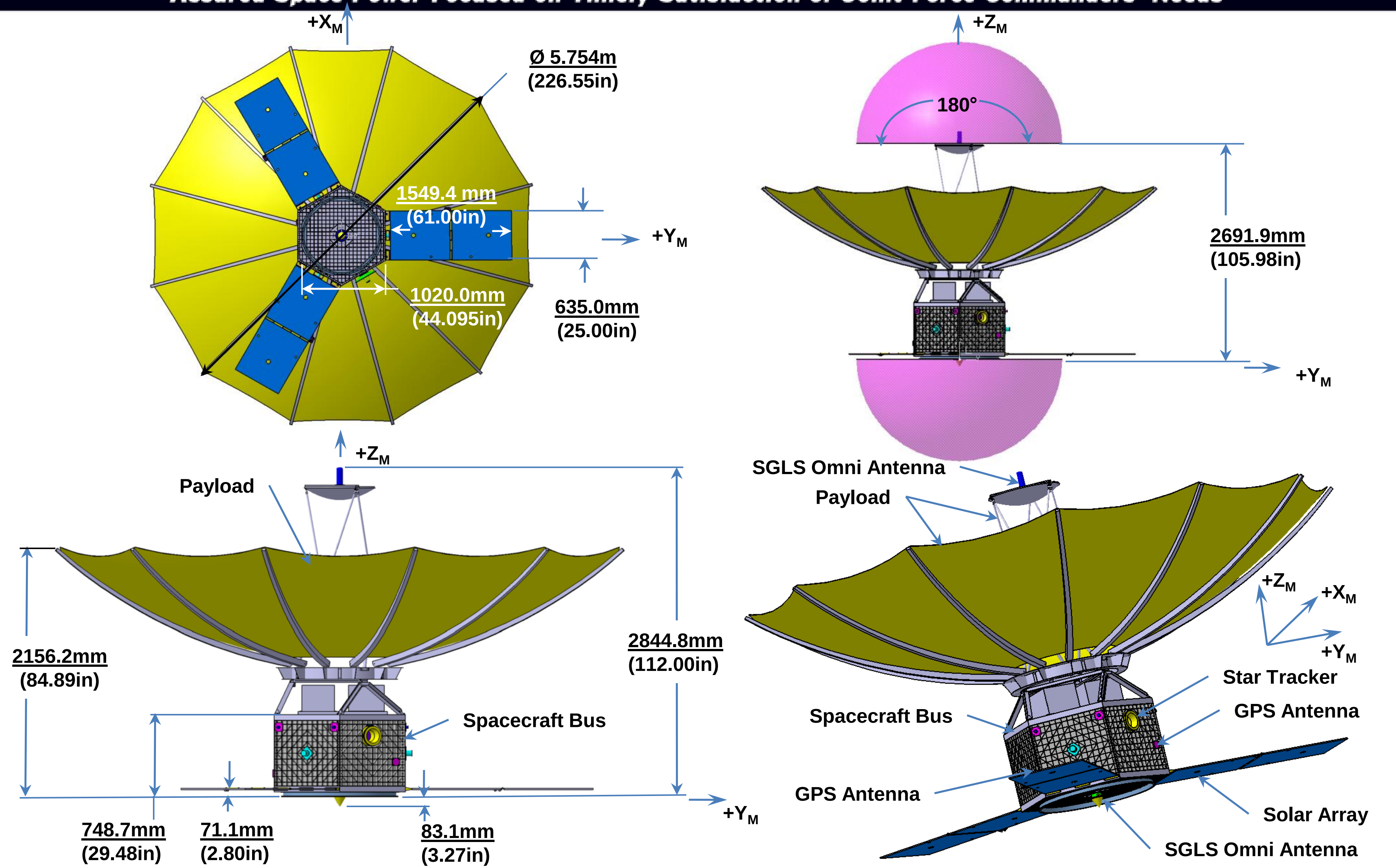

Understanding the Contract

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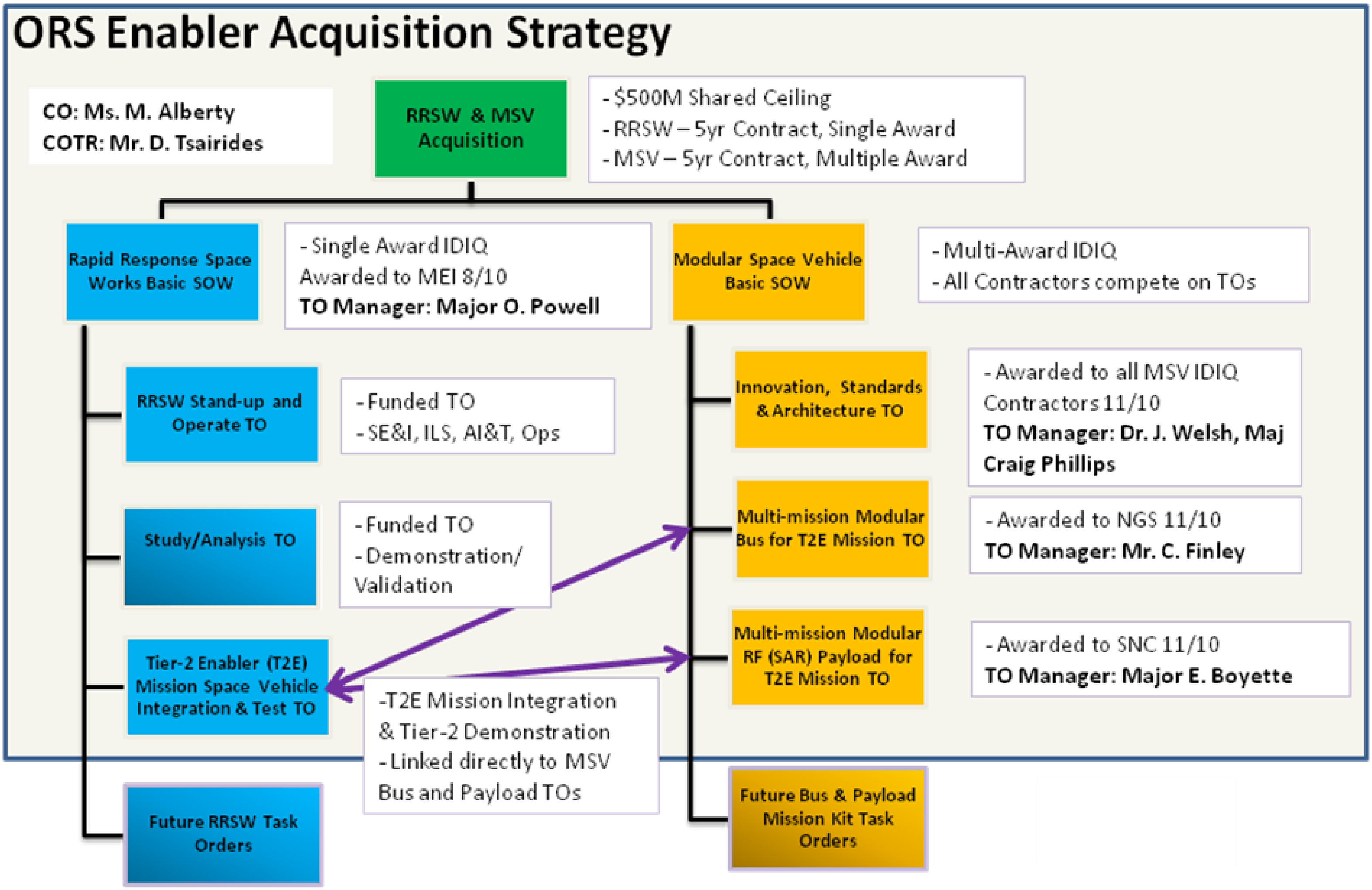

T2E Mission Schedule Summary

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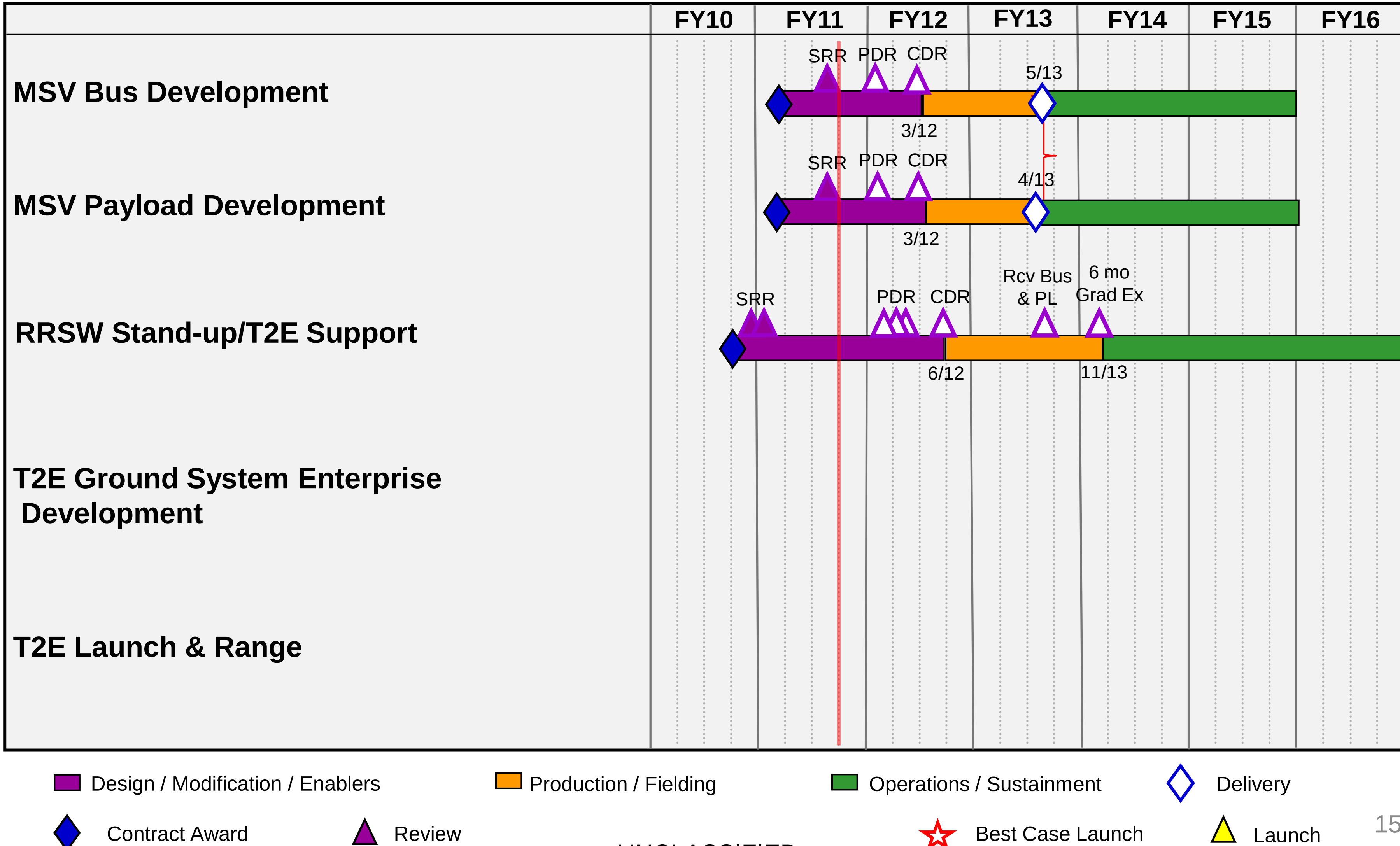

MSV Bus Architecture and a T2E Configuration

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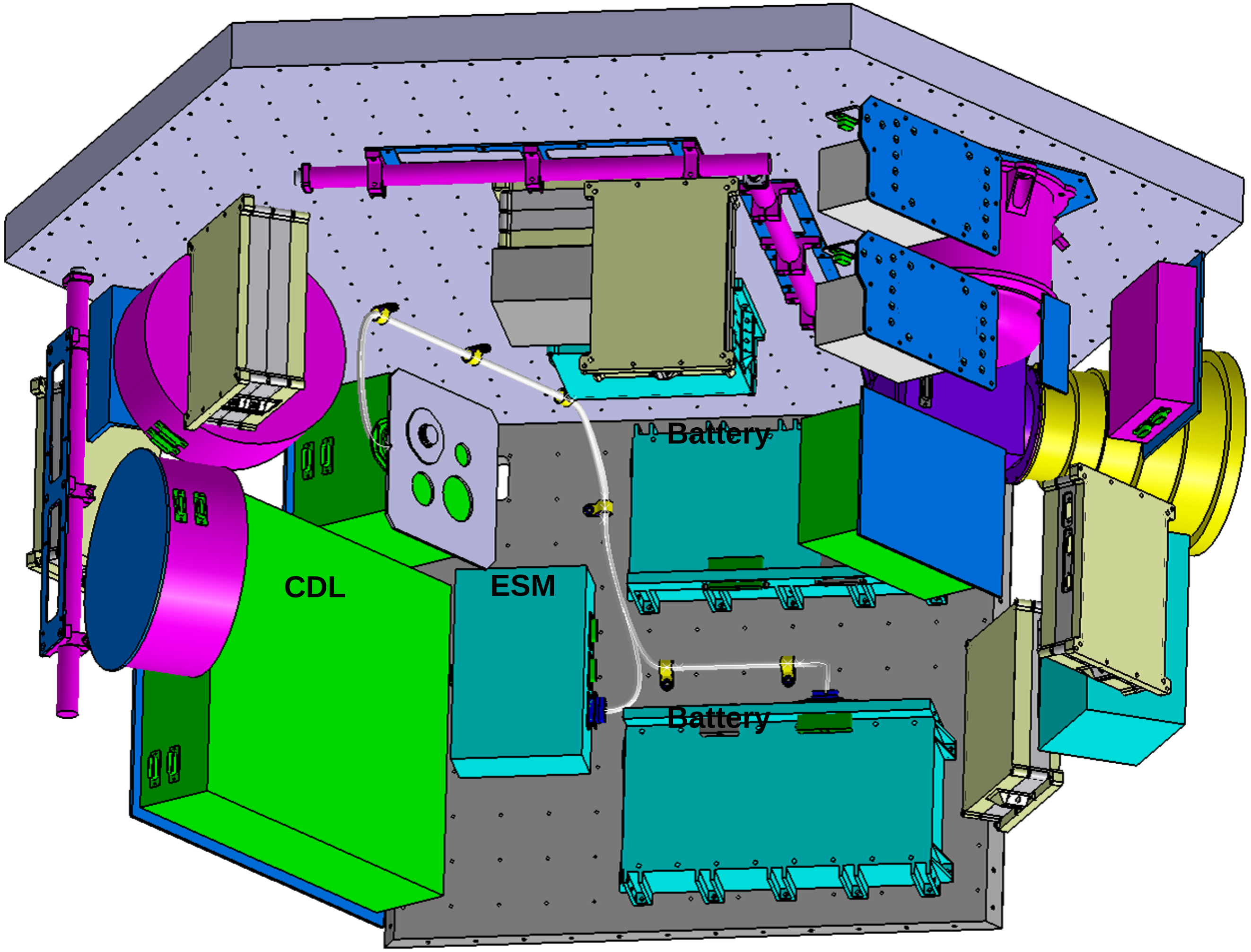

Modular, Scalable, and Rapidly Configurable
Subsystems

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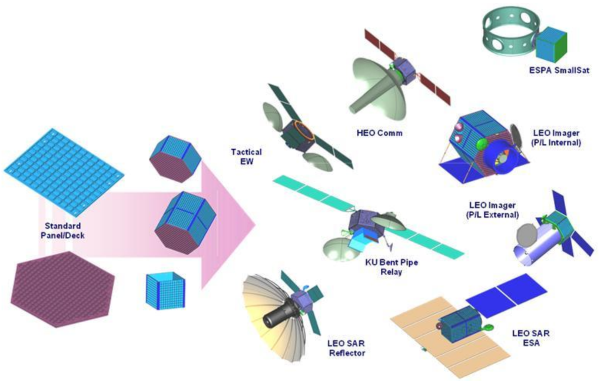
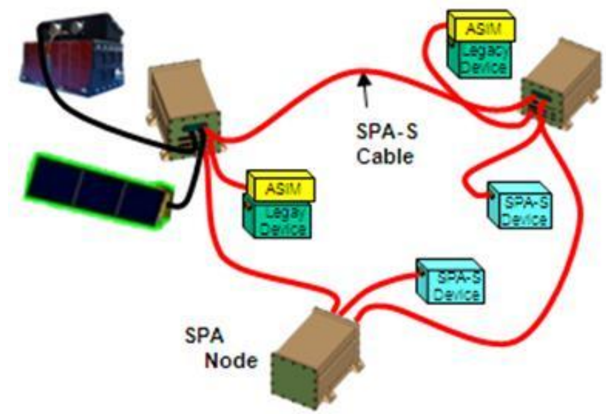
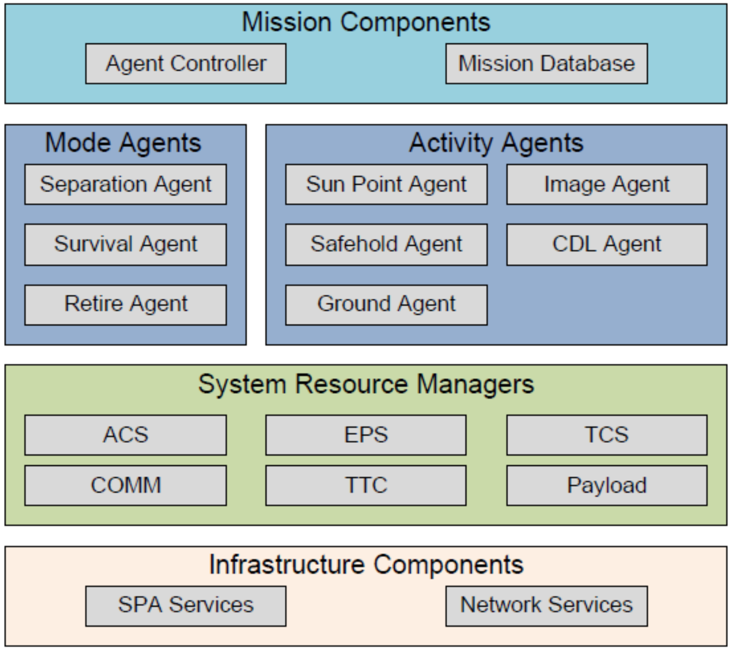
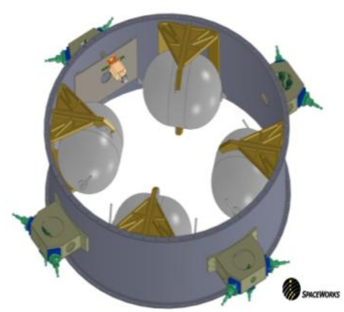
- Structure
- C&DH
- Thermal Control
- Prop
- ADCS
- EPS
- FSW









So . . . how are we doing?

Successes and Challenges

Mass/Power/Complexity = Challenge

- Modular SPA-S design requires an additional 64 kg of mass and 124 W of power over an optimized design
- SPA-S design requires additional hardware development
  - SPA-S compatible IPDRs with internal Spacewire routers
  - Four new types of ASIMs
- SPA-S design also requires significant modification and testing of SSM software

Scalable ADCS = Success

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Trade Parameters	Option-1	Option-2	Option-3	Option-4 (Option 1 & 2 hybrid)	Option-5 (Option 1 & 3 hybrid)
Configuration Description:	(Baseline) Goodrich 16B200	Goodrich 26E700	Goodrich 26E400	Goodrich 16B200 (Z axis) Goodrich 26E700 (X & Y axes)	Goodrich 16B200 (Z axis) Goodrich 26E400 (X & Y axes)
Performance Parameters					
(List applicable Key parameters here)					
Momentum Capacity (N-m-sec)	16.5 N-m-sec	26 N-m-sec	26 N-m-sec	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Max Reaction Torque (N-m)	0.2 N-m	0.7 N-m	0.4 N-m	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Speed Range (rpm)	+/-5100 rpm	+/-2020 rpm	+/-2020 rpm	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Mass, single RWA (kg)	7.5 kg	14.5 kg total (10.4 kg for RWA, 4.1 kg for electronic box/driver)	12.4 kg	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Total Mass, 3 RWAs	22.5 kg	43.5 kg	37.2 kg	36.5 kg	32.3 kg
Mass Delta from Baseline	N/A	21 kg	14.7 kg	14 kg	9.8 kg
Dimensions	26 cm RWA diameter, 13.5 cm RWA height	38.4 cm RWA diameter, 18.8 cm RWA height, 18cm x 18cm x 9cm driver box dimensions	38.4 cm RWA diameter, 18 cm RWA height	38.4 cm RWA diameter, 18.8 cm RWA height, 18cm x 18cm x 9cm driver box dimensions	38.4 cm RWA diameter, 18 cm RWA height
Separate Electronic Driver Box?	No	Yes	No	Yes	No
Peak Power Max (W)	250 W	380 W	250 W	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Steady State Power at 1000 rpm (W) (note: this does not equate to equal SV rate since wheel momentum is different for various options at this speed)	15 W	22 W	22 W	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Steady State Power at Max Speed (W)	28 W at 5100 rpm	28 W at 2020 rpm	28 W at 2020 rpm	1-option 1 RWA + 2 option 2 RWAs	1-option 1 RWA + 2 option 3 RWAs
Max Estimated SV Rate at 75% RWA capacity*	X-axis: 2.11 deg/sec, Y-axis: 2.11 deg/sec, Z-axis: 3.28 deg/sec	X-axis: 3.33 deg/sec, Y-axis: 3.33 deg/sec, Z-axis: 5.17 deg/sec	X-axis: 3.33 deg/sec, Y-axis: 3.33 deg/sec, Z-axis: 5.17 deg/sec	X-axis: 3.33 deg/sec, Y-axis: 3.33 deg/sec, Z-axis: 3.28 deg/sec	X-axis: 3.33 deg/sec, Y-axis: 3.33 deg/sec, Z-axis: 3.28 deg/sec
Max Estimated SV Acceleration*	X-axis: 0.034 deg/sec^2, Y-axis: 0.034 deg/sec^2, Z-axis: 0.053 deg/sec^2	X-axis: 0.119 deg/sec^2, Y-axis: 0.119 deg/sec^2, Z-axis: 0.185 deg/sec^2	X-axis: 0.068 deg/sec^2, Y-axis: 0.068 deg/sec^2, Z-axis: 0.106 deg/sec^2	X-axis: 0.119 deg/sec^2, Y-axis: 0.119 deg/sec^2, Z-axis: 0.053 deg/sec^2	X-axis: 0.068 deg/sec^2, Y-axis: 0.068 deg/sec^2, Z-axis: 0.053 deg/sec^2
Maneuver Time to Travel 90 deg (single axis maneuver)	X-axis: ~73 sec, Y-axis: ~73 sec, Z-axis: ~58 sec	X-axis: ~39 sec, Y-axis: ~39 sec, Z-axis: ~31 sec	X-axis: ~51 sec, Y-axis: ~51 sec, Z-axis: ~41 sec	X-axis: ~39 sec, Y-axis: ~39 sec, Z-axis: ~58 sec	X-axis: ~51 sec, Y-axis: ~51 sec, Z-axis: ~58 sec
Maneuver Time to Travel 180 deg (single axis maneuver)	X-axis: ~103 sec, Y-axis: ~103 sec, Z-axis: ~82 sec	X-axis: ~55 sec, Y-axis: ~55 sec, Z-axis: ~44 sec	X-axis: ~73 sec, Y-axis: ~73 sec, Z-axis: ~58 sec	X-axis: ~55 sec, Y-axis: ~55 sec, Z-axis: ~82 sec	X-axis: ~73 sec, Y-axis: ~73 sec, Z-axis: ~82 sec
Level	TRL 9	TRL 9	TRL 9	TRL 9	TRL 9

Scalable EPS = Success

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Trade Parameters	Option-1	Option-2	Option-3
Configuration Description:	**Baseline 3 orbits in a for for: Eclipse + 10 min PL OPS + 10 min CDL Comm OPS + Slew**	**4 orbits in a row for: Eclipse + 10 min PL OPS + 10 min CDL Comm OPS + Slew**	**7 orbits in a row for: Eclipse + 10 min PL OPS + 10 min CDL Comm OPS + Slew**
Performance Parameters			
Total SlewTime & Assumptions	Slew from/to sun point twice per orbit for a total slew time of 8 Minutes per orbit	Slew from/to sun point twice per orbit for a total slew time of 8 Minutes per orbit	Slew from/to sun point twice per orbit for a total slew time of 8 Minutes per orbit
SA Load	600 W	600 W	800 W
Battery	2 LCROSS	Add 2 LCROSS Batteries, 6,5 kg each (4 total)	Remove existing LCROSS batteries. Add two JWST Batteries, 19.8 kg each, W=37.7cm, L=26.5cm, H =17.7 cm
****SA Configuration (# of wings & Panels)***	3 wings, 6 panels	No change from baseline, 3 wings, 6 panels	Add one wing (4 wings total) Dimensions and weight are the same as for baseline wing
Electronics (ESM, SAC)	1 SAC, 1 ESM	No change from baseline, except possibly additional ESM (TBS)	Need to add one SAC module and one ESM
Dimensions	See MEL	See MEL	Each battery: W=37.7cm, L=26.5cm, H =17.7 cm
SA on SB Config	SRR pckg	See Attached Slides	Added one wing. Moved one wing 60 degrees to make layout symmetric
Mass (SB only)	244.95 kg	258.34 kg (8.34 kg above req)	276.27 kg (26.27 kg above req)
MOI (SB + Payload)	Ixx = 281 kg-m2 Iyy = 284 kg-m2 Izz = 187 kg-m2	Ixx = 286 kg-m2 Iyy = 286 kg-m2 Izz = 190 kg-m2	Ixx = 311 kg-m2 Iyy = 286 kg-m2 Izz = 198 kg-m2
Agility (Slew & Accel)	TBS	TBS	TBS
Mechanical Interface Accommodation	NA	No impact	No impact

EPS Option 2 (Internal)

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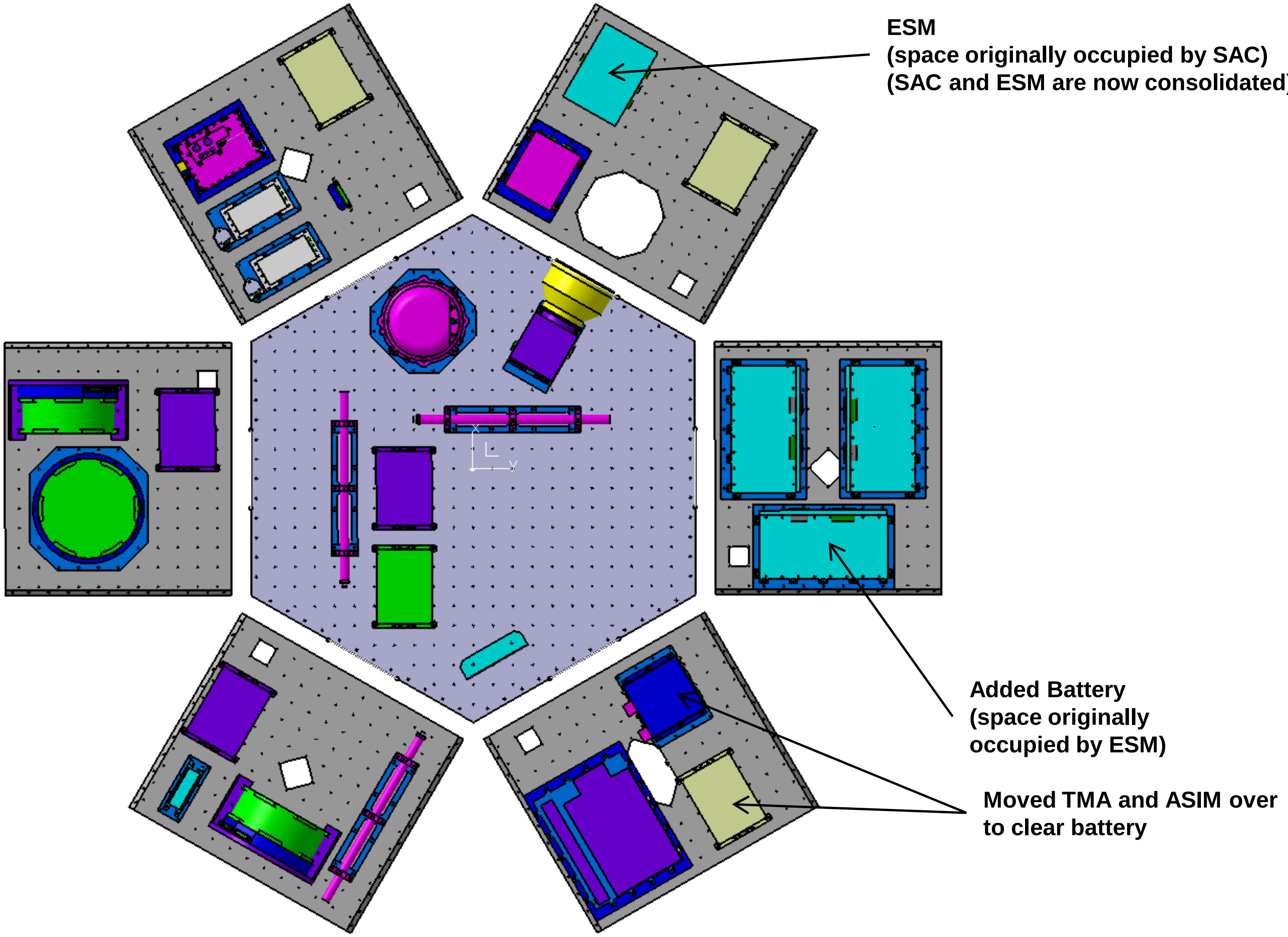

EPS Option 2 (External)

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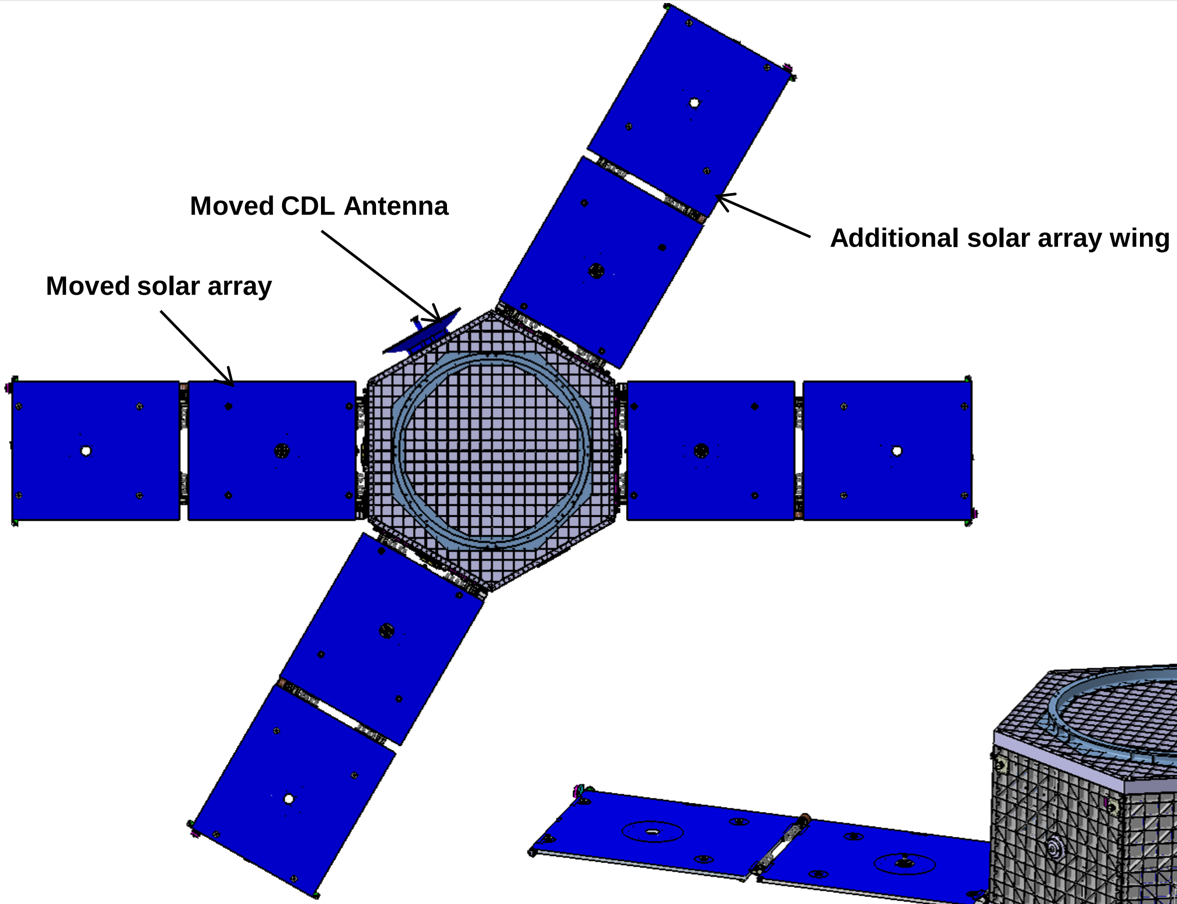

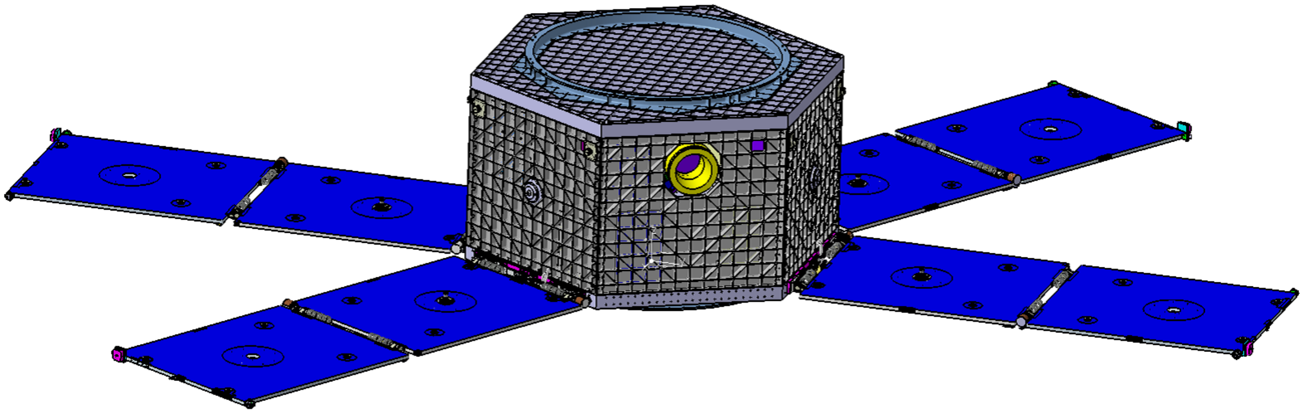

Scalable FSW = Challenge

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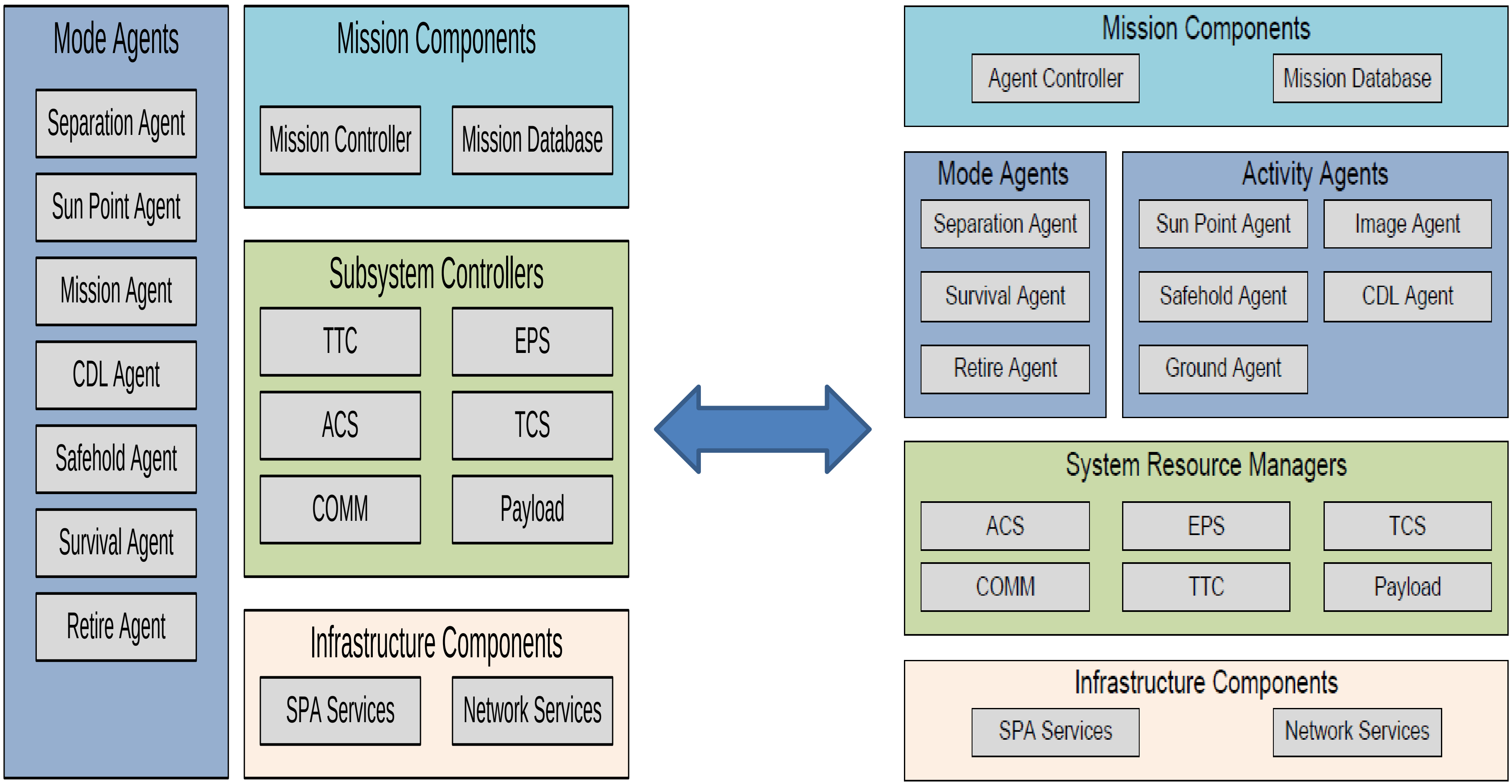

Conclusion

The Problem(s)

Cost (Everyone) + Speed (ORS)

- Put the myth of the "Standard Bus" to rest
  - Americans have requirements; requirements drive tailoring → **design a solution that is affordably tailorable**

- Make space a volume enterprise → from volume comes efficiency
  - "Componentize" it
  - Adopt the standard . . .

    that NASA has . . . that the Swedish have . . . that AeroAstro has . . .

Questions?