In-House Build Efficiencies: PM, SE, & MA

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Agenda

- Background/Objective
- Research methodology
- In-house vs. external spacecraft builds: impact on total PM/SE/MA costs
- End-to-End mission efficiency with in-house builds
- Conclusions/Recommendations

Background

- Existing analyses demonstrate that hardware is a fairly reliable predictor of mission level PM, SE, MA costs
- Statistical analysis has shown these functions also depend on multiple mission- and organization-specific characteristics (Hahn, 2014)
  - Mission start year, mission class, Competed/PI-Led, subcontracted bus, etc.
- External vs. internal spacecraft build is shown to be a cost driver in mission level PM, SE, and MA costs
  - Missions with external builds (spacecraft built outside of the managing institution) showed lower PMSEMA costs at the mission level
  - However, this analysis did not include additional (and non-trivial) wrap costs incurred by the spacecraft vendor for high reliability missions
- Many competed missions rely on out of house spacecraft builds
- Previous analysis does not capture efficiencies that may exist for PI-Led missions that rely on in-house spacecraft builds
- “One size fits all” estimating methodology not appropriate for this critical mission element
  - Particularly important for validating costs of competed, PI-Led missions

Objective

- Do competed missions with in-house spacecraft builds benefit from efficiencies of an end-to-end mission capability?
- For missions with external builds, are the apparent savings in mission PM/SE/MA offset by additional PM/SE/MA costs at the spacecraft level?
- If end-to-end mission efficiencies with in-house spacecraft builds exist, do they translate either to:
  - More available dollars for payload and science?
  - Lower mission cost overall—more bang for the buck?

Methodology: Data Collection & Normalization

- CADRe as primary data source, with some internal APL data
- Focus on PI-Led missions
  - Some directed to increase dataset for in-house builds
  - 15 data points over all; 7 external builds; 8 internal builds
  - Missions had sufficient cost data at both the mission and spacecraft level
  - No missions with launches before 2001
- CADRe Parts A and B for technical and programmatic data; Part C for cost data
- All costs inflated to $FY15 using NASA New Start Inflation Index
  - Particularly important for apples-to-apples comparison since we are analyzing both cost factors and absolute dollars
- PMSEMA includes both mission-level costs (WBS 01,02,03) and spacecraft PMSEMA (identified costs within WBS 05,06)
- Flight system costs collected for cost-to-cost factor analysis
  - Flight system defined as spacecraft, payload, and IA&T
  - Excludes PMSEMA in the spacecraft as it is part of the broader PMSEMA analysis

Methodology: Missions

Analysis Missions				
	Mission	Launch	Class	PI-Led/Directed
Subcontracted Spacecraft	Genesis	2001	Discovery	PI-Led
	Stardust	2003	Discovery	PI-Led
	DAWN	2007	Discovery	PI-Led
	Kepler	2009	Discovery	PI-Led
	GRAIL	2011	Discovery	PI-Led
	Juno	2011	New Frontiers	PI-Led
	MAVEN	2013	Mars Scout	PI-Led
In-House Spacecraft Builds	CONTOUR	2002	Discovery	PI-Led
	MESSENGER	2004	Discovery	PI-Led
	New Horizons	2006	New Frontiers	PI-Led
	STEREO**	2006	LWS	Directed
	LRO	2009		Directed
	SDO	2010	Flagship	Directed
	Van Allen Probes	2012	LWS	Directed
	LADEE	2013		Directed

- Fairly limited dataset, but both in-house and out of house spacecraft equally represented
- Dominated by Discovery Class missions: largest class of competed missions represented in CADRe; subcontracted spacecraft more common

***While the STEREO mission was managed by GSFC, the CADRe shows APL costs in WBS 01,02,and03 for mission PM, SE, MA. APL built the spacecraft managed instrument delivery, observatory I&T, and the launch campaign, mission operations, and GDS. For this reason it is grouped with in-house builds.*

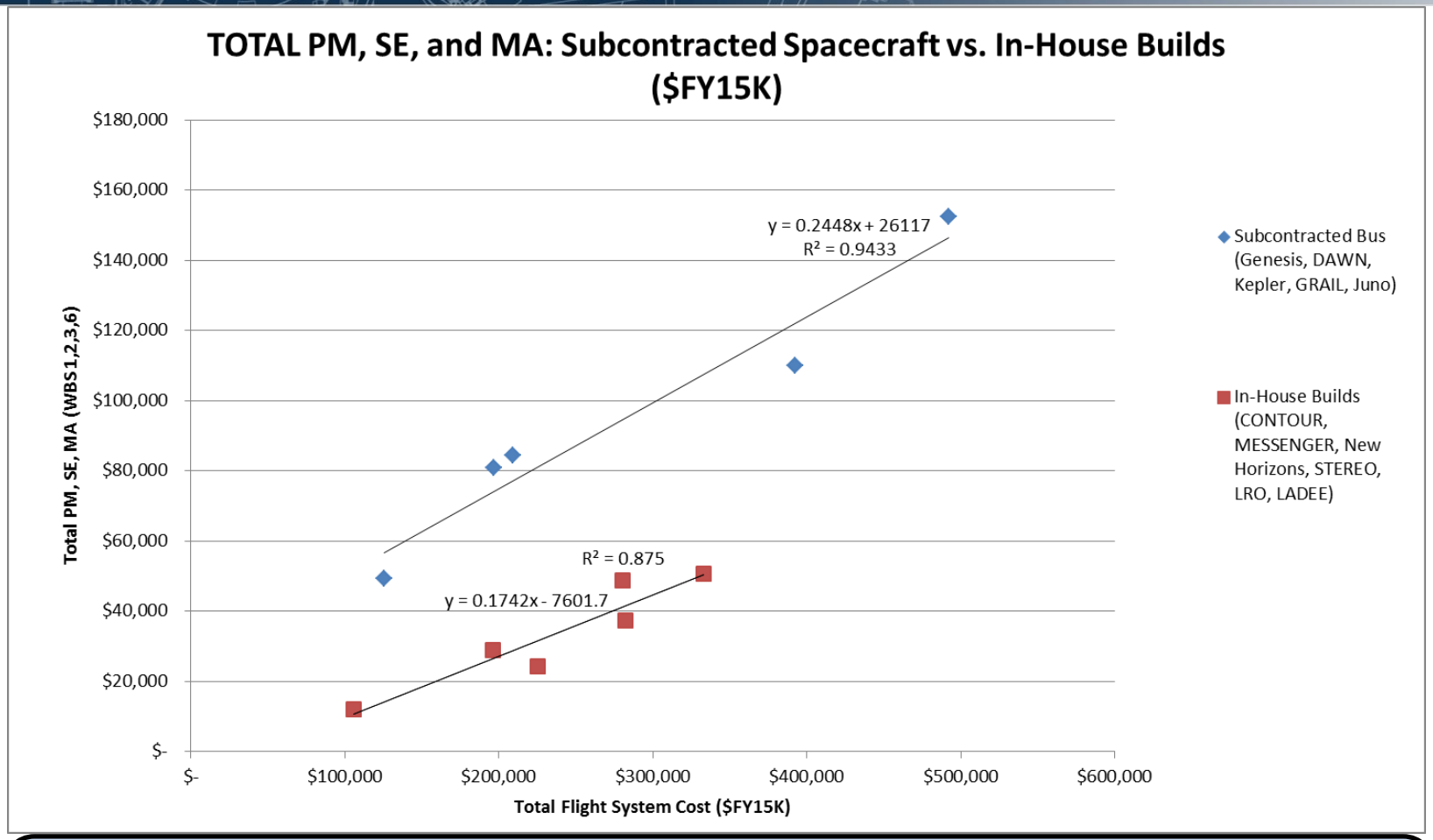
In-House vs. External Build Spacecraft: PM/SE/MA as % of Flight System

In-House vs. External Build Spacecraft: PM/SE/MA as Percentage of Flight System							
Mission	Mission PM/SE/MA (WBS 1,2,3)	Flight System (WBS 5,6 & 10)	Mission PMSEMA as % of Flight System	WBS06 (S/C) PMSEMA	Flight System less S/C PMSEMA	TOTAL PMSEMA (WBS 1,2,3,6)	TOTAL PMSEMA as % of Flight System
Subcontracted Build Average	**$ 46.6**	**$ 307.8**	**14%**	**$ 41.4**	**$ 272.4**	**$ 82.0**	**33%**
In-House Build Average	**$ 40.1**	**$ 306.0**	**13%**	**$ -**	**$ 306.0**	**$ 40.1**	**13%**
Average PI-Led	$ 24.5	$ 221.6	11%	$ -	$ 221.6	$ 24.5	11%
Average Directed	$ 49.6	$ 366.6	14%	$ -	$ 366.1	$ 49.6	14%

Note: Averages are calculated for each metric using mission data points that are not shown here for proprietary reasons. The percentages are NOT calculated using averages

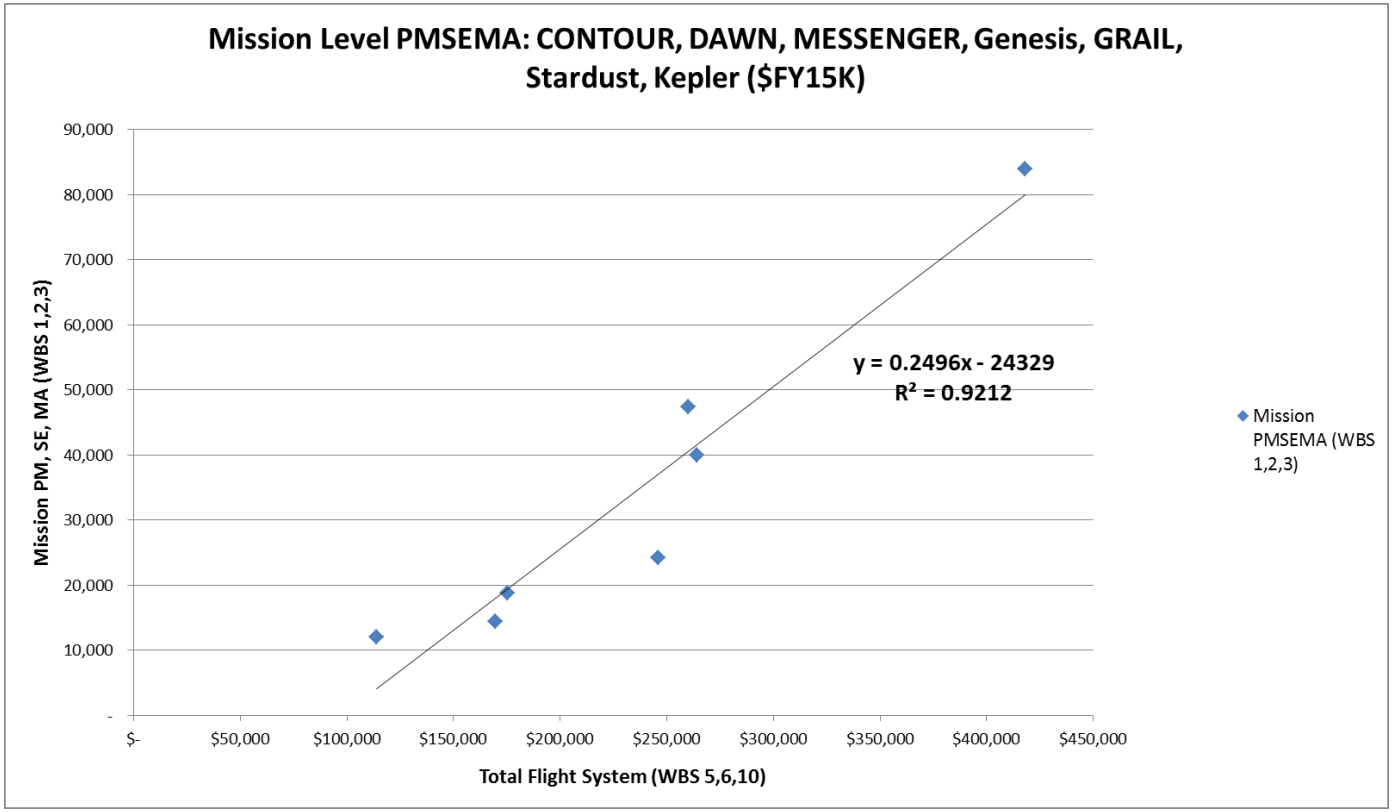
- At the mission level, PMSEMA looks comparable between in-house and subcontracted spacecraft missions both in absolute dollars (~$40M) and in cost as a percentage of total flight system (13-14%)
- After including PMSEMA at the spacecraft level, subcontracted builds show a cost-to-cost factor of 33% vs. 13% for in-house builds (along with double the absolute dollars on average)
- Comparing PI-Led missions only, in-house builds show lower flight system costs, lower PMSEMA costs, and lower PMSEMA cost as % of the flight system

In-House vs. External Build Spacecraft: *Total* PM/SE/MA as Function of Flight System



Clear distinction between in-house builds and subcontracted spacecraft, both in total PMSEMA and total Flight System costs; strong R-squared with simple linear regression for both groupings

Discovery Class Missions: Mission Level PMSEMA as Function of Flight System



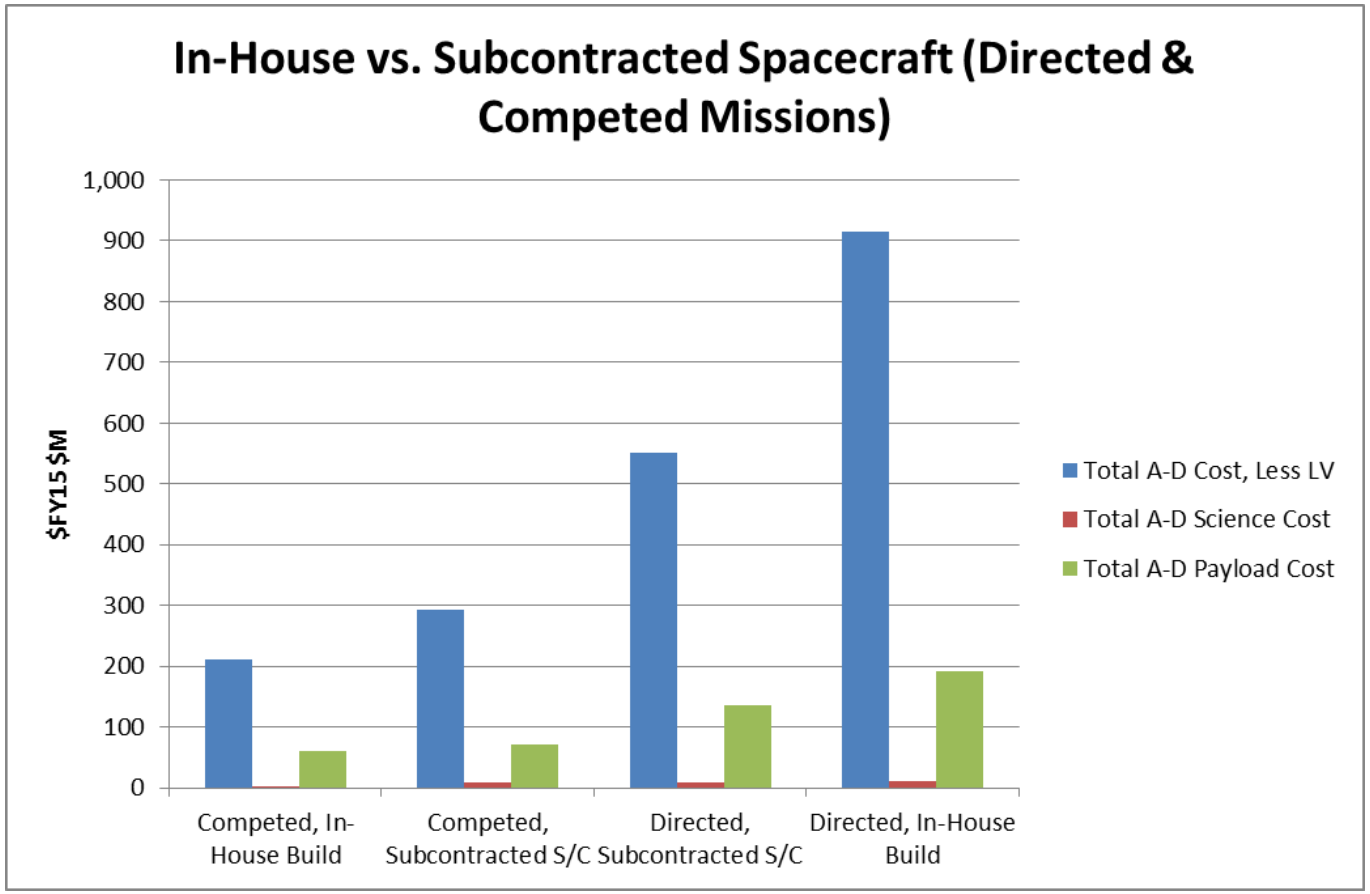
- **Not** including spacecraft-level PMSEMA can be deceiving in estimating total PMSEMA costs
- Analysis of just mission PMSEMA Discovery-class missions shows no distinction between in-house and external builds

Impact on Total Mission Cost

Average A-D Cost: Mission, Payload, & Science ($FY15, $M) In-House vs. Subcontracted Spacecraft (Directed and Competed Missions)					
Mission Type	**Total A-D Cost, Less LV**	**Total A-D Science Cost**	**Total A-D Payload Cost**	**Technology Development?**	**Typical Mission Class**
Competed, In-House Build	$ 211.1	$ 2.1	$ 59.3	Min-Mod	Discovery, New Frontiers
Competed, Subcontracted S/C	$ 292.0	$ 8.9	$ 71.4	Minimal	Discovery
Directed, Subcontracted S/C	$ 550.7	$ 9.5	$ 136.2	Mod-High	Mars, LWS, New Frontiers
Directed, In-House Build	$ 913.8	$ 10.0	$ 191.3	Significant	Flagship, Mars

- **On average, competed missions with in-house builds show the lowest total development cost (excluding launch vehicle)**
  - Lower overall PMSEMA costs not linked to increased resources expended on payload, science
  - Payload and science costs also lowest for competed, in-house build missions
  - Could mission end-to-end capability facilitate multi-faceted organizational efficiency?
- **As expected, directed missions with in-house spacecraft builds show overall highest A-D development, payload, and science costs**
  - Generally Flagship-class missions with significant technology development/architecture investment
  - Different classification than competed in-house builds

Impact on Total Mission Cost



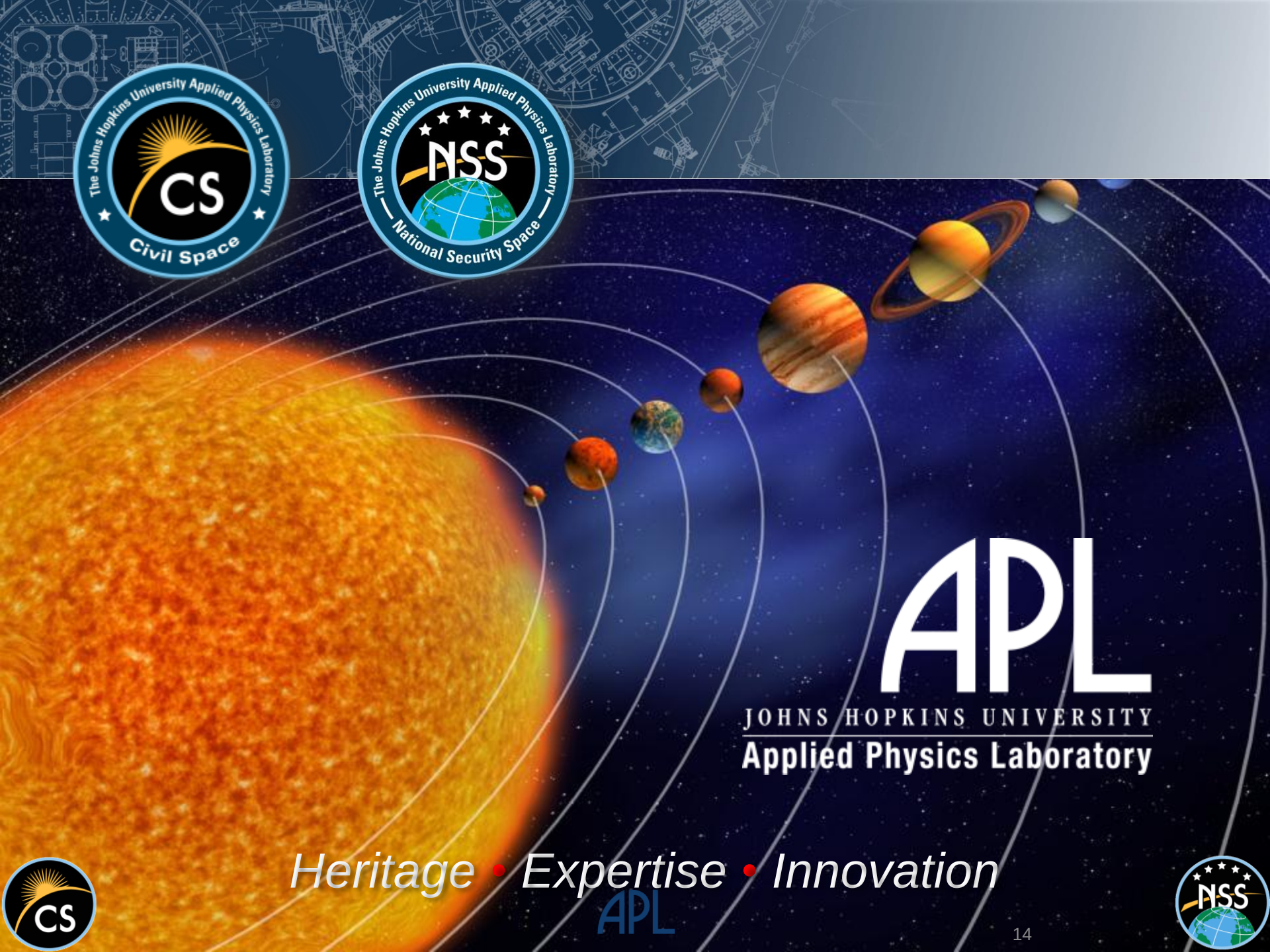
Increasing cost from competed missions with in-house spacecraft builds through directed missions with in-house spacecraft builds

Conclusions & Recommendations

- There is an inherent efficiency in total PM, SE, MA costs—both in absolute dollars and in percentage of flight system—with in-house spacecraft builds
- An end-to-end mission capability facilitates management and engineering efficiency
  - With all hardware built in-house, mission level PMSEMA is responsible for both mission and spacecraft oversight
  - Core team with multiple hats; roles not duplicated at the spacecraft level
  - No need for multiple layers of oversight; no organizational conflicts
  - Streamlined, familiar processes
- Lower flight system costs for competed missions with in-house spacecraft builds
- Lowest overall mission development cost for competed missions with in-house builds
- Cost savings of a procured bus *may* be offset by the additional cost of oversight
- In-house vs. external build should be a critical variable when estimating *total* PMSEMA costs of competed missions

Special Thanks

- Sally Whitley and Nicole Krepps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