Concept for 2033 Crewed Mars Orbital Mission with Venus Flyby: A Programmatic Cost Tool (PCT) Case Study

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Agenda

- Brief Introduction to PCT
- Introduce the 2033 Mars Orbital mission with Venus Flyby Concept
- PCT’s use for the 2033 Concept

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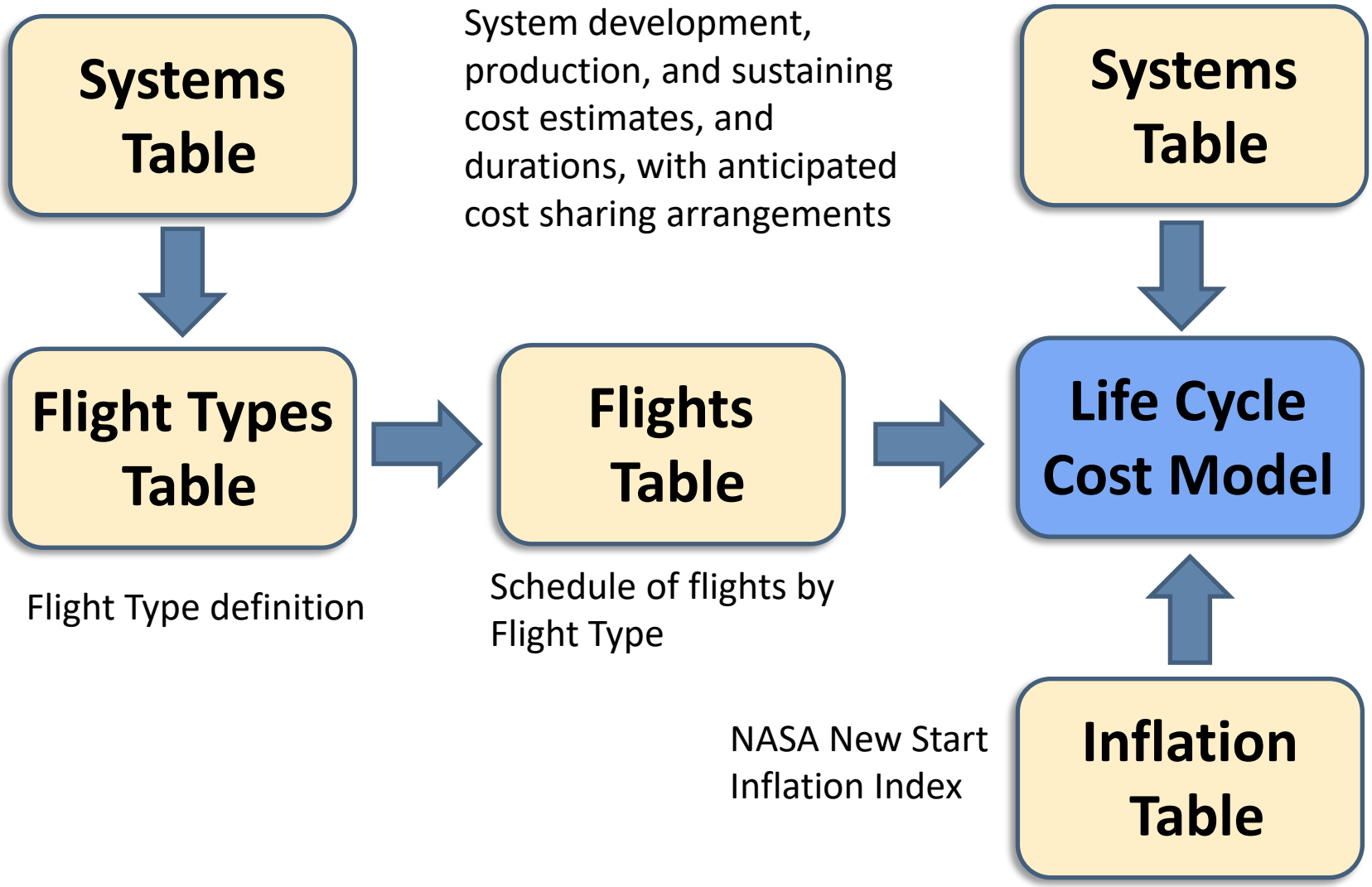
Programmatic Cost Tool (PCT) Intro

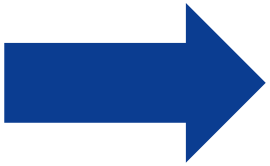
- The Programmatic Cost Tool is designed to integrate human spaceflight architectures, schedules and costs to enable assessments of affordability.
  - If you know the following:
    - The Systems*** you need to fly [Systems]…
    - …which Systems should launch together [Flight Types]…
    - …and how many of each Flight Types you'd like to launch, and when you'd like to launch them [Flights]…
  - Then PCT will tell you:
    - When to start and how much funding will be needed by year for development, production and sustainment costs, for each System needed to fly.
  - ***PCT does *not* estimate the costs of your Systems.

Overview of the Main Elements of PCT



Programmatic Cost Tool (PCT) Trades

- Utilizing PCT is rapid, thus it can support trades:
  - Adding/removing Flights
  - Re-phasing missions
  - Flight stack comparisons
  - Architecture comparisons

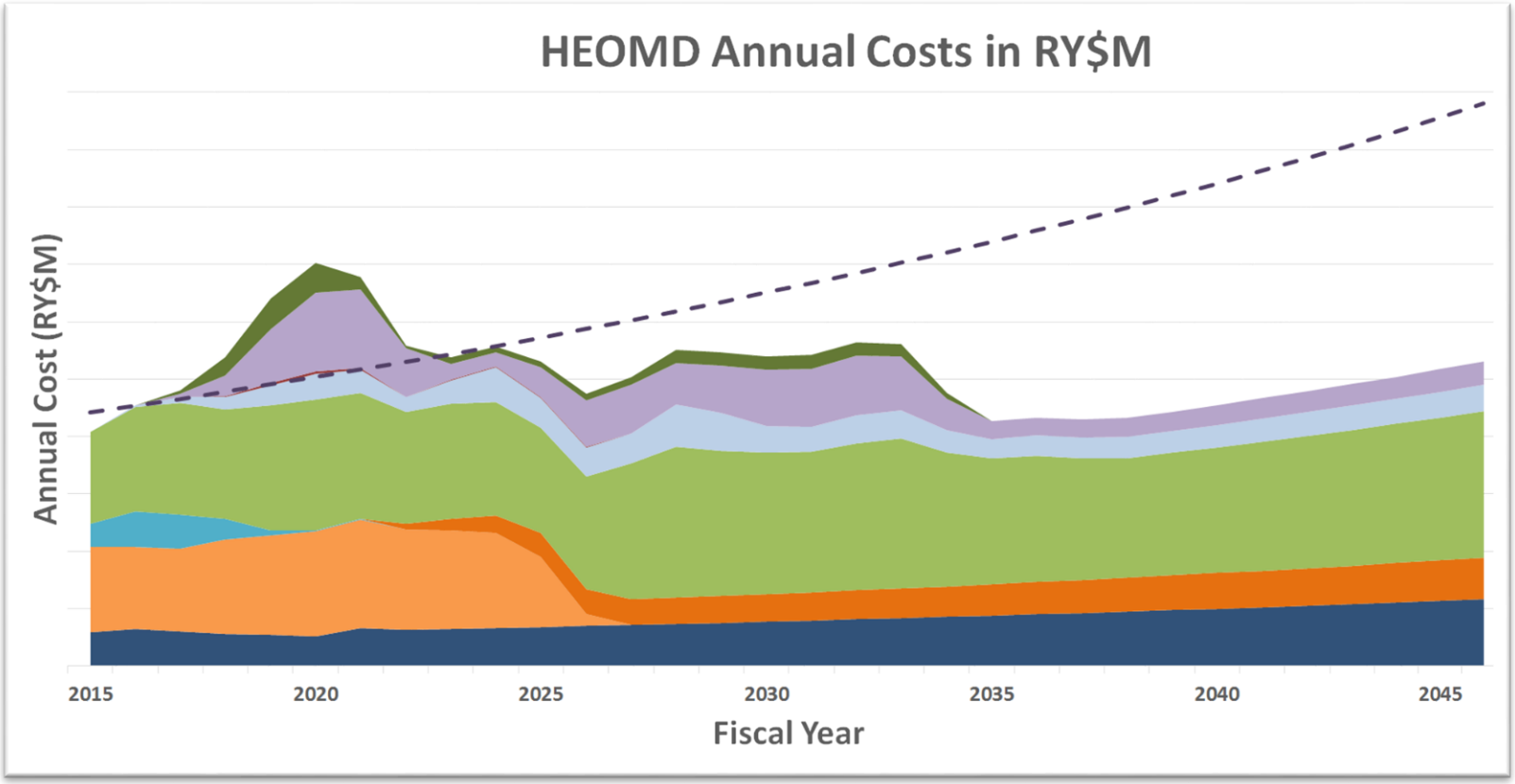


PCT Allows for Affordability to be part of the Architectural Trade space

Programmatic Cost Tool (PCT) Trades

PCT Allows for Affordability to be part of the Architectural Trade space

The PCT sand chart showed the example architecture below was overbudget.
Programmatic trades facilitated by PCT were needed to confirm to the projected budget



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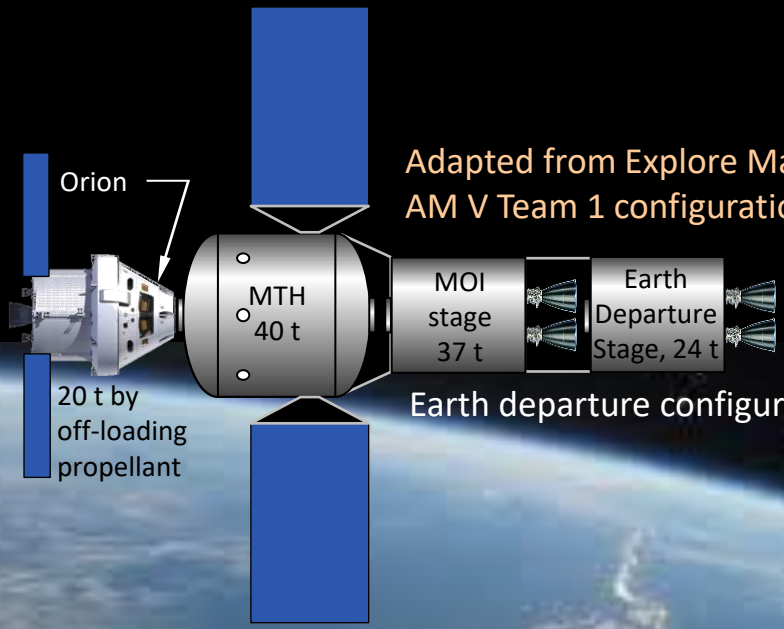
Concept for Humans to Mars Orbit in 2033

- Would utilize current technology systems
- Would minimize development & mission risk with less complex systems
  - Traditional hypergolic chemical propulsion with common stage design and engines
- Launched in segments by SLS and commercial rockets
- Assembled in high Earth orbit or at Gateway
- Crew would return directly to Earth in Orion capsule
- 2033 offers a unique short-stay orbital mission (~1.6 year total duration)



Adapted from Explore Mars AM V Team 1 configuration

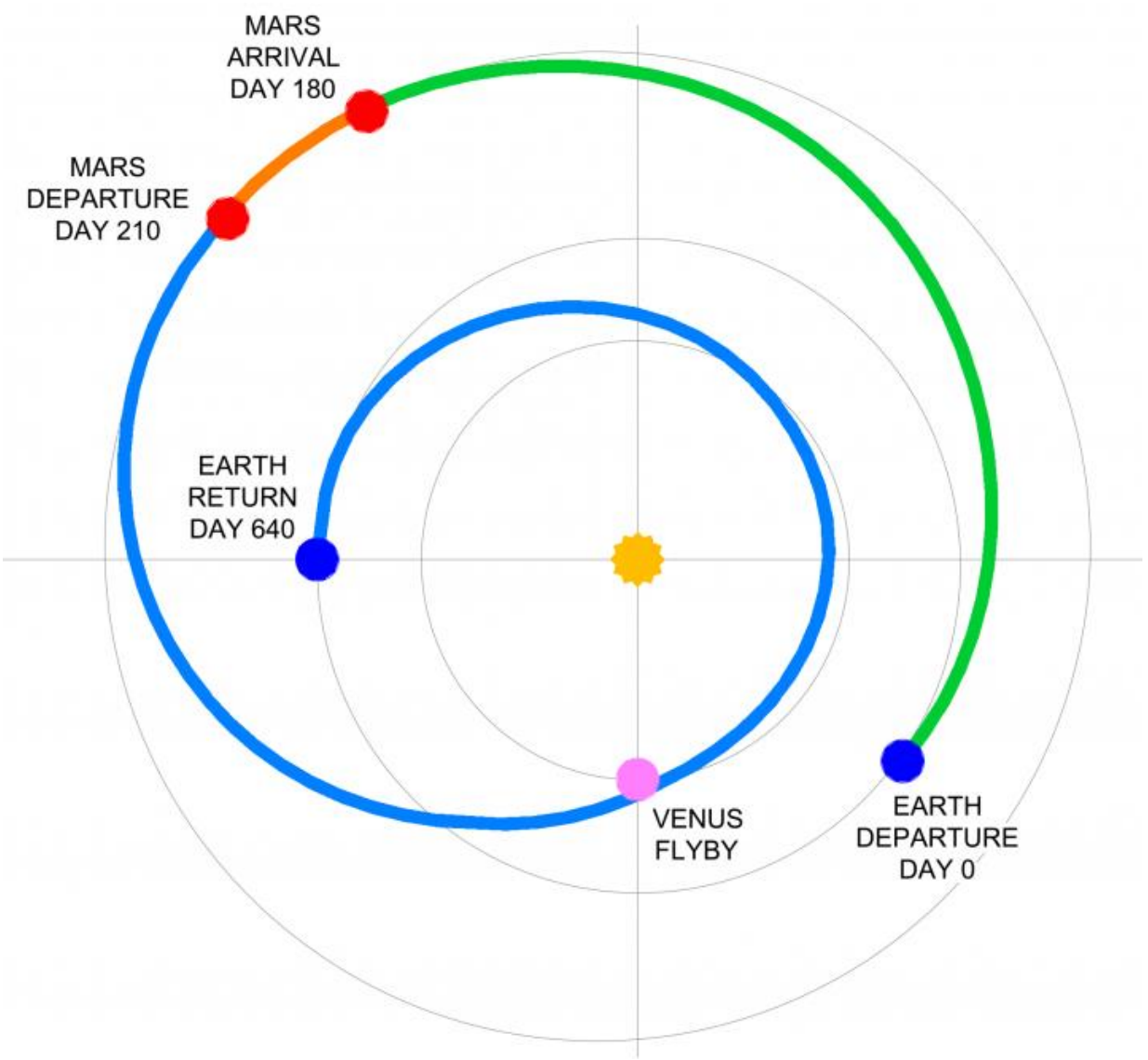
Earth departure configuration for crew

- <u>2033 short stay mission</u>:
  - The first crew to travel to both Mars and Venus
  - Not a “one-off”, but a pathfinder for crew transport and for landing missions to follow, perhaps as early as 2037

2033 Short-Stay Mars Orbital Mission Concept

Crew of 4; 570 day round trip

4 SLS launches
13 commercial launches



2033 Short-Stay Mars Orbital Mission Concept

Crew of 4; 570 day round trip

4 SLS launches
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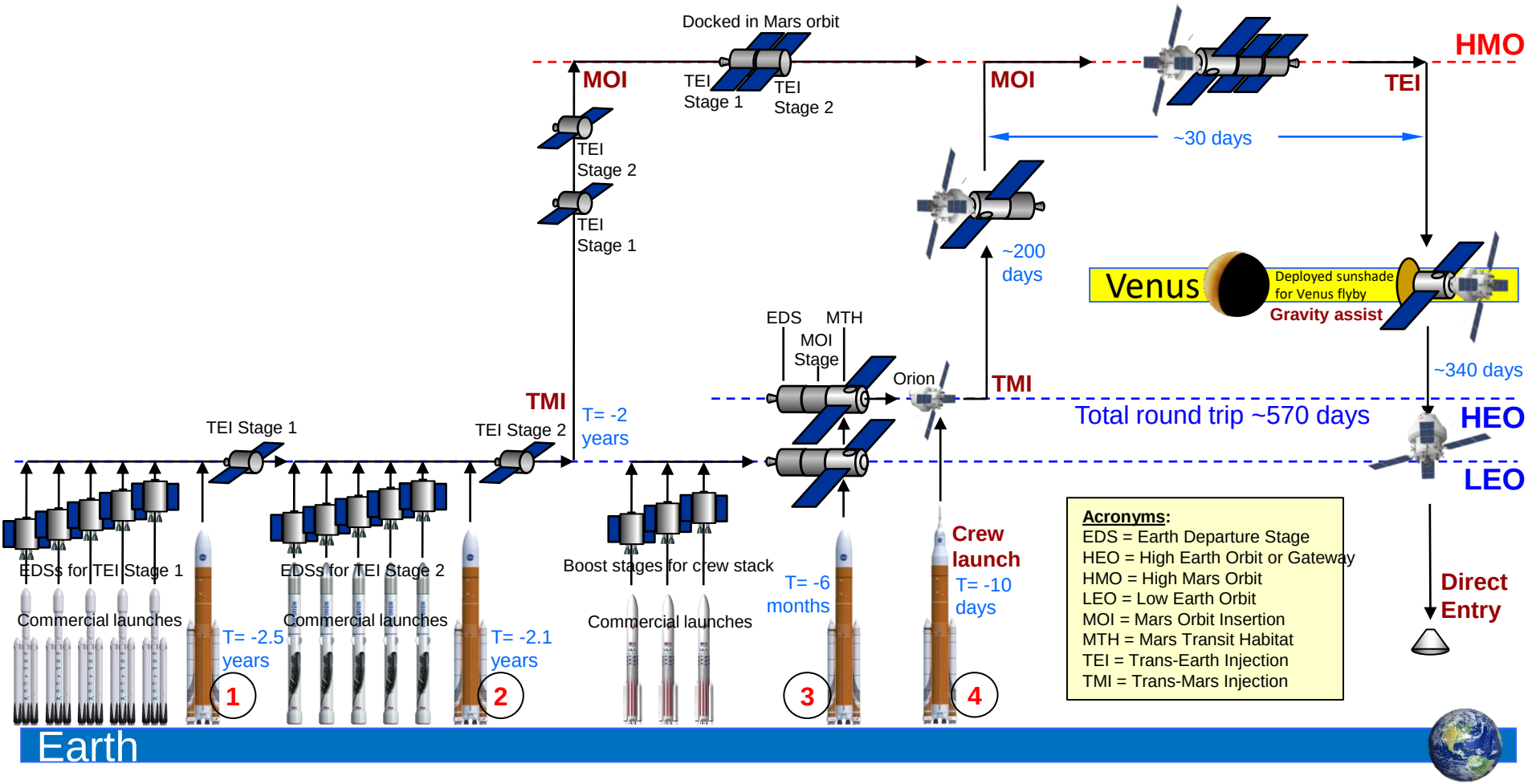
This mission concept example utilizes 17 low-cost conventional hypergolic propulsion stages with a common design (with 3 different tank lengths), possibly using RS-72 or XLR-132 (AR31) engines.

Mars



Earth

Cost Estimate Above Expected NASA Budget

- Key vehicles for the 2033 concept are currently in NASA's plans. It was assumed these could be made available for the mission within the expected NASA budget for this time frame:
  - Orion at a launch rate of one per year (only 1 is needed for the mission)
  - SLS Block 2 at a launch rate of two per year
- It is assumed that a prototype MTH will be developed and tested at Gateway in the late 2020s within the expected NASA budget
- It is assumed that ground system and mission operations costs could be covered within the expected NASA budget
- The costs estimated here are only for systems not within the expected NASA budget for the time frame being considered:
  - Biprop stages, flight MTH for the mission, modifications to Orion for extended lifetime and new heatshield, and commercial launches
- Costs were estimated and spread over time using the Programmatic Cost Tool (PCT) developed by the Aerospace Corporation and JPL. Estimates include 50% margin on development costs and 25% margin on production costs. Costs are in millions of dollars.

2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	TOTAL
$204 M	$1,018 M	$1,745 M	$1,944 M	$1,679 M	$2,059 M	$2,874 M	$2,317 M	$1,646 M	$871 M	$480 M	$439 M	$451 M	$17,728 M

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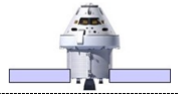
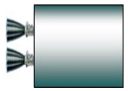
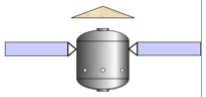
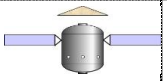
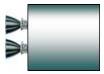
Systems Needed (Input Table 1 of 3)

Systems Table

Activate Systems Form

System ID	System Name	System Graphic	System Short Name	System Development Cost (FY13$M)	System Development Time (Years)	Development - Production Overlap (Years)	System Production Cost (FY13$M)	System Production Time (Years)	System Sustainment Cost / Year (FY13$M)
29	Orion Mars Variant (Blk 2)		Orion (Blk 2)						
30	Biprop Stage -1 (100mt)		Biprop-100						
31	Biprop Stage -2 (60mt)		Biprop-60						
32	Biprop Stage -3 (45mt)		Biprop-45						
33	Mars Transit Habitat		MTH						
34	Falcon 9 Heavy (Expendible)		F9H						
35	Venus Gravity Assist Sunshade		Sunshade						

Flight Types (Input Table 2 of 3)

Flight Type ID	Flight Type Name	Crew Size	LV System Icon	Launch Vehicle System Short Name	Primary Payload System Icon	Primary Payload System Short Name	Primary Payload Qty Manifested	Secondary Payload System Icon	Secondary Payload System Short Name	Secondary Payload Qty Manifested
1	Boost Stage Launch			F9H		Biprop-60	1			
2	TEI Stage Launch			SLS (Blk 2)		Biprop-100	1			
3	Mars Transit Stack Launch			SLS (Blk 2)		MTH	1		Biprop-45	2
4	Orion Crew Launch	4		SLS (Blk 2)		Orion (Blk 2)	1			

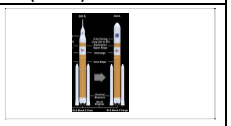
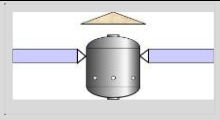
Flight Types (Input Table 3 of 3)

Activate Flights Form

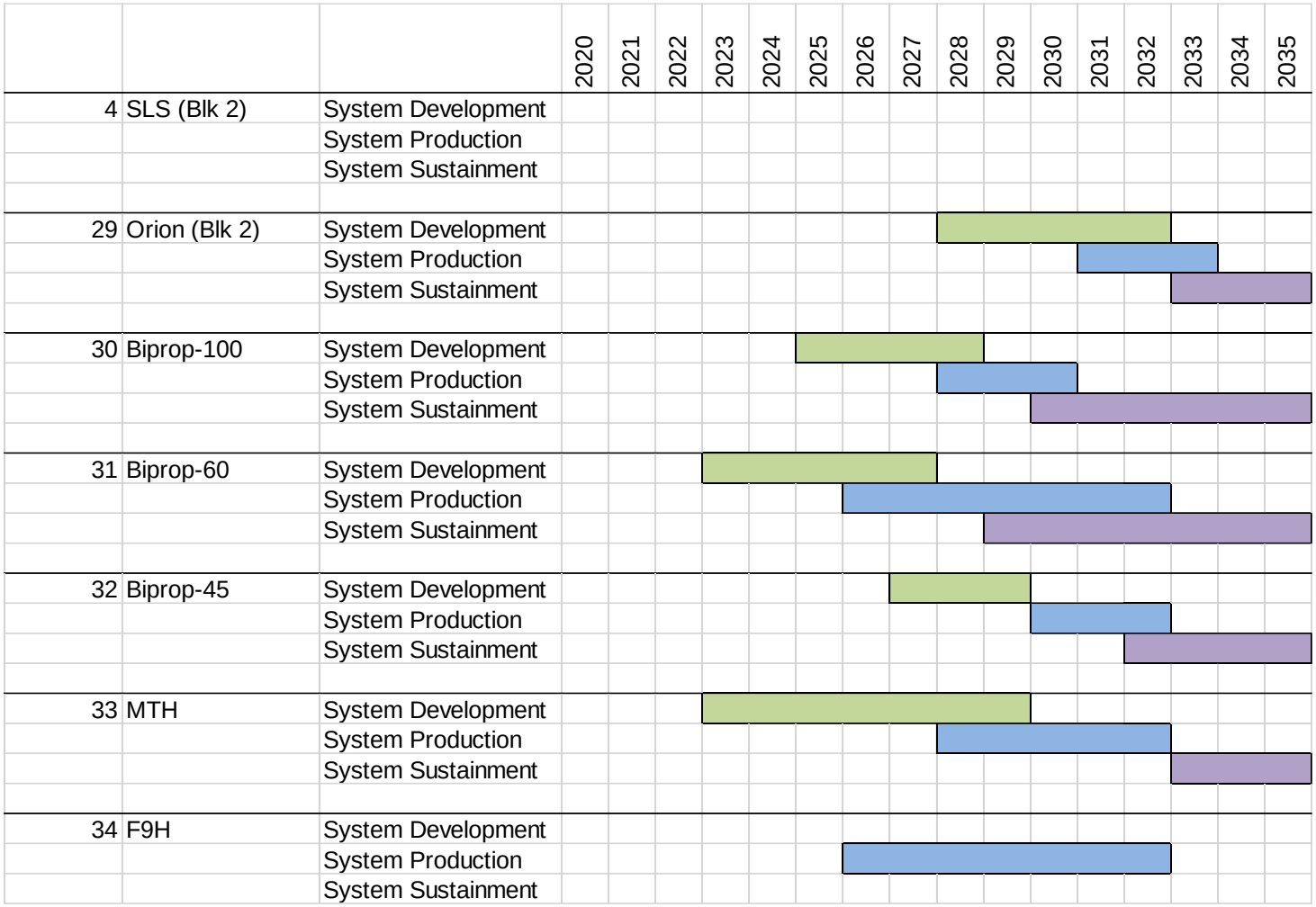
Flights Table

Flight ID	Flight Name	Flight Type ID	Flight Type Name	Nominal Flight Start Date (FY)	Nominal Flight End Date (FY)	Include In Ops Profile (T/F)
1	TEI 1 Boost Stage 1	1	Boost Stage Launch	2028	2035	TRUE
2	TEI 1 Boost Stage 2	1	Boost Stage Launch	2028	2035	TRUE
3	TEI 1 Boost Stage 3	1	Boost Stage Launch	2029	2035	TRUE
4	TEI 1 Boost Stage 4	1	Boost Stage Launch	2029	2035	TRUE
5	TEI 1 Boost Stage 5	1	Boost Stage Launch	2029	2035	TRUE
6	TEI 2 Boost Stage 1	1	Boost Stage Launch	2029	2035	TRUE
7	TEI 2 Boost Stage 2	1	Boost Stage Launch	2030	2035	TRUE
8	TEI 2 Boost Stage 3	1	Boost Stage Launch	2030	2035	TRUE
9	TEI 2 Boost Stage 4	1	Boost Stage Launch	2030	2035	TRUE
10	TEI 2 Boost Stage 5	1	Boost Stage Launch	2030	2035	TRUE
11	Transit Stack Boost Stage 1	1	Boost Stage Launch	2031	2035	TRUE
12	Transit Stack Boost Stage 2	1	Boost Stage Launch	2032	2035	TRUE
13	Transit Stack Boost Stage 3	1	Boost Stage Launch	2030	2035	TRUE
14	TEI Stage 1	2	TEI Stage Launch	2030	2035	TRUE
15	TEI Stage 2	2	TEI Stage Launch	2030	2035	TRUE
16	Mars Transit Stack	3	Mars Transit Stack Launch	2032	2035	TRUE
17	Crew Launch	4	Orion Crew Launch	2033	2035	TRUE

Outputs: Dance Card

Populate Graphics	2028	2029	2030	2031	2032	2033
Flight	TEI 1 Boost Stage 1	TEI 1 Boost Stage 3	TEI 2 Boost Stage 2	Transit Stack Boost Stage 1	Transit Stack Boost Stage 2	Crew Launch
Flight Type	Boost Stage Launch	Boost Stage Launch	Boost Stage Launch	Boost Stage Launch	Boost Stage Launch	Orion Crew Launch
Launch System	F9H	F9H	F9H	F9H	F9H	SLS (Blk 2)
Launch System Picture						
Primary Payload	Biprop-60	Biprop-60	Biprop-60	Biprop-60	Biprop-60	Orion (Blk 2)
Primary Payload Picture						
Flight	TEI 1 Boost Stage 2	TEI 1 Boost Stage 4	TEI 2 Boost Stage 3		Mars Transit Stack	
Flight Type	Boost Stage Launch	Boost Stage Launch	Boost Stage Launch		Mars Transit Stack Launch	
Launch System	F9H	F9H	F9H		SLS (Blk 2)	
Launch System Picture						
Primary Payload	Biprop-60	Biprop-60	Biprop-60		MTH	
Primary Payload Picture						
Secondary Payload					Biprop-45	
Secondary Payload Picture						
Tertiary Payload					Sunshade	
Tertiary Payload Picture						

Outputs:



			2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
4	SLS (Blk 2)	System Development																
		System Production																
		System Sustainment																
29	Orion (Blk 2)	System Development																
		System Production																
		System Sustainment																
30	Biprop-100	System Development																
		System Production																
		System Sustainment																
31	Biprop-60	System Development																
		System Production																
		System Sustainment																
32	Biprop-45	System Development																
		System Production																
		System Sustainment																
33	MTH	System Development																
		System Production																
		System Sustainment																
34	F9H	System Development																
		System Production																
		System Sustainment																

- Note: This study only tracked *additional* costs to NASA to enable this concept, hence
  - SLS is not tracked.
  - Orion costs here are the additional costs needed to modify Orion to enable the concept.

Outputs:

Development Costs By FY (in FY13$M)

System ID	System Short Name	System Development Start FY	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
29	Orion (Blk 2)	2028											
30	Biprop-100	2025											
31	Biprop-60	2023											
32	Biprop-45	2027											
33	MTH	2023											
34	F9H	2026											
35	Sunshade	2028											

Production Costs By FY (in FY13$M)

System ID	System Short Name	System Production Time (Years)	2026	2027	2028	2029	2030	2031	2032	2033
29	Orion (Blk 2)	3								
30	Biprop-100	3								
31	Biprop-60	3								
32	Biprop-45	3								
33	MTH	5								
34	F9H	3								
35	Sunshade	2								

Sustainment Cost By FY (in FY13$M)

System ID	System Short Name	System Sustainment Start FY	2029	2030	2031	2032	2033	2034	2035
29	Orion (Blk 2)	2033							
30	Biprop-100	2030							
31	Biprop-60	2029							
32	Biprop-45	2032							
33	MTH	2033							
34	F9H								
35	Sunshade								

Outputs:

Total Cost (in FY13$M)

System ID	System Short Name	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
29	Orion (Blk 2)													
30	Biprop-100													
31	Biprop-60													
32	Biprop-45													
33	MTH													
34	F9H													
35	Sunshade													

Concluding Thoughts:

- The Programmatic Cost Tool can quickly process multi-year, multi-launch, multi-system architectures to answer questions of affordability. Moreover, when the answer is that the architecture is not affordable for given budget, PCT supplies a rapid framework to perform trades to optimize the architecture for cost and schedule.

Questions?

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Backup Slides

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