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Launch Vehicle Market and Future State

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NLS

Insight &

Approval

Commercial Acquisition Expertise

Commercial Space Act National Space Policy National Space Transportation Policy



Tolerance; Less Insight & Approval







Evolution of LSP Contracted Set of Launch Services

USSF Phase 2 Contract is in place for 5 years and up to 34 missions

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Many new vehicles from nontraditional companies

Increase in interest in NASA Heavy Lift missions

CCP launches on Falcon 9 including a used vehicle this year Since 1998 and since 2009 presentation to the last Planetary Decadal Survey options have increased, performance is higher, and prices are lower

NUNCH SERVICES PROGRAM







- LSP's NLS 2 contract for Class A, B, and C missions requires a successful flight of the "common launch vehicle configuration" (CLVC) before specific mission proposal
- All new (beyond major mods) US developed LV's in the last 25 years took 6 to 7 years from beginning of funded development to initial first launch success
- First successful launch of CLVC delayed 15 months (avg) predicted 1 year in advance
- Third successful launch of CLVC delayed 35 months (avg) predicted 1 year before 1st scheduled launch; 3 successful launches minimum needed for NASA certification
- Worldwide, 25% of new CLVC's since mid-2006 had a failure in the first 3 launches (89% success in launches 1, 2, and 3)
 - First 3 launches ('86 to mid '06): 33% had a failure and only 80% success overall
 - "Modern" history shows first flight failures are coming from brand new rockets mostly from organizations with no experience



Launch Service Acquisition and New Vehicle Certification Schedule







Full Mission Budget for LSP Launch Services

Includes more than awarded price to supplier

Telemetry



NASA launch service budget in the press release is not the contract value to supplier





History of NASA Planetary Missions and Heavy



Mission	Multiple non planetary	Maven	Juno	Mars Perseverance	Lucy	Dart	Psyche	HALO- PPE	Parker Solar Probe
Vehicle	Last 4 Delta II	Atlas V 401	Atlas V 551	Atlas V 541	Atlas V 401	Falcon 9 FT Recoverable	Falcon Heavy	Falcon Heavy Expendable	Delta IV Heavy
Award	July '12	Oct '10	Oct '07	Aug '16	Feb '19	April '19	Feb '20	Feb '21	March '15
Launch at Award	'14 - '16	Nov '13	Aug '11	July '20	Oct '21	June '21	July '22	May '24	July '18
Full Mission Budget at award	\$509M (\$127M average)	\$187M	\$190 mpetition a Requireme ngful chang budge	\$243M nd Mission nts drive ges in missio	\$148M	\$69M (3 current non planetary missions average ~\$100M)	\$117M	\$332 (mission requires long payload fairing)	\$389M Awarded Basic Service contract price including 3 rd stage



- Falcon Heavy Expendable planetary performance is ~40-50% higher than Delta IV Heavy
 - Recoverable Falcon Heavy similar to Atlas V 551 up to C3=20
 - Configuration that recovers side cores and expends center core is possible but not on contract
- Falcon 9 Recoverable performance is equal or better than Atlas V 401 for C3 up to 6
 - Expendable ConOp is not on contract and performance is estimated when needed (website 4000 kg to Mars), and SpaceX may choose to propose a Falcon Heavy instead
- Antares similar to Delta II 7925 Heavy to C3 of greater than 10
- Vulcan VC6S performance > Delta IV Heavy thru C3 of at least 55
 - VC2S performance is close to but less than Atlas V 551 thru C3 of about 20
 - Vulcan Heavy upgrade, required for USSF in 2023, gives 5-7% increase based on ULA website
- New Glenn's contracted capability is considered "conservative by Blue" and similar to Atlas V 551 up to C3=10; No contract capability above C3=30



Previous, Current and New Intermediate/Heavy NLS Vehicles



Planetary Performance Comparison (kg)												
LV	ILC or Flights	C3=0	C3=10	C3=20	C3=40	C3=55						
Falcon Heavy (Expendable)		15010	12345	10115	6640	4690						
Falcon Heavy (Recoverable)	3/3	6690	5130	3845	1805	660						
Falcon 9 FT (Recoverable)	103/103	3310	2220	NA	NA	NA						
Antares 232	9/9	1675	1315	1015	NA	NA						
Vulcan VC0S- from ULA website VC2S VC6S Rounded down to nearest 100 kg	Late '21 or early '22 (ref Spaceflightnow 5/21/21)	>2300 5900 10800	4700 9100	3700 7600	1900 5100	900 3600						
Atlas V 401 Atlas V 551	87/87	3035 6105	2425 5060	1880 4140	985 2670	490 1910						
Delta IV H (No longer available)	12/13	10185	8460	6995	4700	3395						
New Glenn (only recoverable) Rounded down to nearest 100 kg	Late '22	7100	4900	2300	NA	NA						





180.000

USSF Defined 180 Inch Payload Faring Envelope Enables Competition







- Falcon Heavy Category 3 Certification progressing for completion in plenty of time before the Psyche mission
- Falcon 9 FT Launch Service awards/budgets are great, but increasing ٠
 - LSP Design Certification Review reuse assessment closed; conditional acceptance for IXPE/DART
 - Long standing LSP documented risks have been closed —
 - 11 launches in 2019, 26 in 2020, already 20 in first half 2021; Starlink ready to fill open launch slots! —

Starship:

- Multiple launches equal a single mission (lunar, L1/L2, planetary)
- Spiral development concept explained to LSP a couple of years ago is likely out of date —
- Progress can be seen via 2nd stage "hops" in Texas —
- First stage demonstration coming soon; configuration not publicly available —
- SpaceX talking about different configurations: payloads, landers (which the 2nd stage is) and tankers —
- Starship could take years more to complete to a CLVC NASA could buy: By NASA calculation, SpaceX Falcon 1, 9 and H were within the 6–7-year range for all modern new US LV developments 12



- With USSF award, Vulcan contracted for approximately 17 launches over 5 years beginning in 2022
- First two Vulcan launches connected to NASA (CLPS and Station Resupply)
- Vulcan ILC is following historical delay trends as well
 - First launch is currently 8 months late (assuming December 2021 ILC)
 - With an "all new" configuration (1st methane stage/engine, very large Centaur tanks, up to 15,000 kg Centaur prop offload, new solids, change in personnel, major cost cutting) further delays possible in achieving successful flights 2 and 3 after ILC
 - Any introduction of performance upgrades, such as those required for USSF Heavy, adds schedule risk even if they do not constitute a "new" LV under the NASA NLS definition



Northrup Grumman and Blue Origin Key Points



- Antares has been on NLS 2 contract for many years
 - Price as (stated by NG) and performance are consistent with Delta II with inflation
 - LSP maintains insight and provides advice to NASA JSC for ISS resupply missions
 - 4-meter outside diameter fairing is smaller than Atlas V, but much bigger than Delta II
 - Manifest accommodates planetary mission launch periods
- New Glenn is recently on NLS 2 contract, ILC stated to be late 2022
 - 7-meter outside diameter fairing is standard
 - First build hardware now seen in Florida factory
 - Launch site nearing completion
 - Feb '21 website: "Recent milestones include completion of a New Glenn first stage mock-up simulator, completion of a structural test facility, and hardware milestones for tanks, stage modules, and composite fairings"



- New small LV's with added 3rd stages may be useful to very small planetary missions; e.g., CAPSTONE is 30kg to Near Rectilinear Halo Orbit for \$10M!
- Validated "new space" is no better at predicting schedule (VCLS and Capstone)
 - Using Engine development maturity (thrust, time, qual status) as key item in competition
 - Commercial delay terms are generally in the favor of the LV company
- Approved modified Category 1 certification policy and approach to enable class D missions; created baseline plans; completed 1 certification; active with more
 - Doesn't reduce failures but allows understanding of the major risks; avoid 5x5 risks
 - Does not appear to have meaningful cost implications, some in industry will do it for free
- Approved modified technical oversight policy for class D missions



Summary



- Since the last Planetary Decadal Survey Committee (2009 presentation), options have increased, performance is higher, and prices are lower without considering inflation
- Planetary missions have great priced medium class (i.e., Delta II) options if needed
 - Antares performance is higher with a 4-meter (bigger fairing)
 - Falcon 9 recoverable has even more performance than Antares and a 5-meter fairing, but not as much as Atlas V 401 for C3 > ~5
- At least two options exist for intermediate and heavy class planetary missions
 - Falcon 9, Falcon Heavy, Vulcan and New Glenn don't line up directly with 2009 intermediate performance options
 - Falcon Heavy expendable and Vulcan with 6 solids envelope Delta IV Heavy performance for C3 up to about 55; both for a lower mission budget price
- Competition has been very beneficial, and NASA LSP recommendation is to stick to the standard 5-meter fairing volume to maintain it
 - Flagship missions can individually be assessed for larger fairing volume or upper stages per normal process as the market develops