Airborne Launch Assist Space Access (ALASA)

Mr. Mitchell Burnside Clapp, TTO Program Manager

Briefing prepared for SeeMe Industry Day

DARPA

Tactical
Technology
Office

Airborne launch assist re-defines the launch pad to make space launch affordable, responsive, flexible, and resilient

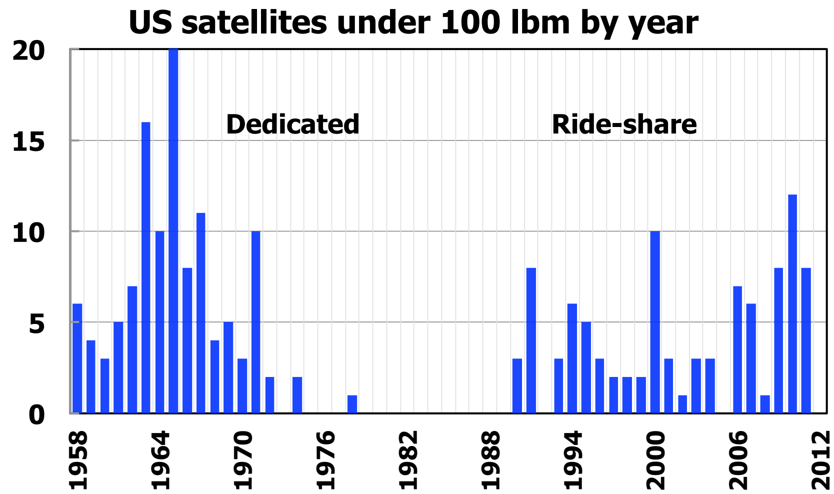
Artist's concept

- Current launch is:
  - Costly – High manpower at fixed facilities, range costs, sustainment costs.
  - Sluggish – Infrastructure permits one launch at a time, weeks to reconfigure.
  - Rigid – Limited launch directions and times for geographic reasons.
  - Brittle – Vulnerable to attack, weather, earthquake, tsunami.
- Solution: Airborne Launch Assist Space Access
  - Affordable – Four major areas of cost savings.
  - Responsive – One day call-up to launch.
  - Flexible – Any orbit, any time.
  - Resilient – Avoids launch site hazards.

Launching satellites without fixed ground facilities is the key to tactical space access.

Pegasus lessons learned

- A *dedicated* launch assist aircraft increases costs (4.5M/year).
  - Conclusion: Use existing aircraft as close to their design mission as possible.
- Scrupulous attention must be paid to range costs.
  - Conclusion: Leverage full capability of airborne launch platform, modern technology.
- Target a market segment with high traffic potential.
  - Conclusion: Frequent payload opportunities have emerged in the small satellite segment (<100 lbm).
  - Current small payloads are forced to accept ride-sharing, and hence another satellite's orbit.



Source: STK database

ALASA enables the small satellite market with 100 pounds to a *dedicated* orbit for $1M

•ALASA defines a flight test demonstrator program based on a 100 lbm to LEO, ~5,000 lbm gross weight vehicle.

- Performance metrics address:
  - Affordability – Demonstrate $1M per flight to LEO (all range costs included).
  - Responsiveness – Demonstrate one day call-up, integrate payload on aircraft.
  - Flexibility – Demonstrate on-board command, control and planning; fly away from constraints of standard ranges.
  - Resilience – Demonstrate ability to relocate, fly from commercial international airport.
- Program features:
  - Up to 36 launches in 2015.
  - 18 Month first phase.
  - "Wooden-Round" design intent.
  - Coordination with FAA/Range/aircraft provider.
- Impact: Reduce risk for future operational capability.

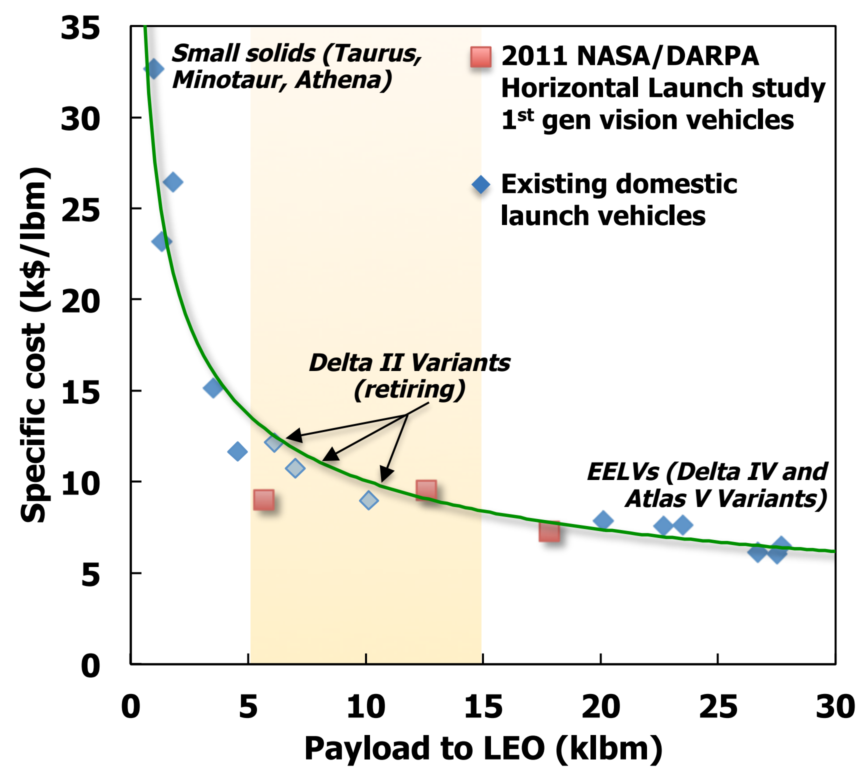
Artist's concept

Artist's concept

DARPA/NASA Study Results: Airborne launch assist increases payload

- DARPA/NASA Horizontal Launch (HL) study indicated ~25-50% increase in payload relative to older systems:
  - Launch assist aircraft provides ~800 ft/s.
  - Altitude ignition reduces back pressure suction on nozzle.
  - Less drag at altitude.
- DARPA/NASA HL study vehicles fell on the conventional domestic launch vehicle cost trendline, but:
  - They were not designed for air launch conditions.
  - No credit was taken for reduced range costs.
  - The study assumed 5-6 events per year flight rate.
  - Conventional cost models applied a business as usual development & operations approach.

System	Ground Launch Payload (lbm)	Air Launch Payload (lbm)	Δ%
Falcon 1e	2,200	2,749	25.0%
Taurus	2,910	4,562	56.8%
Athena II	4,550	5,662	24.4%



DARPA/NASA Study Implications: Taking full advantage of the launch condition increases payload further


DARPA/NASA study concept

- Air Launch Demo Vehicle 2 (from DARPA/NASA study) was essentially a Falcon 1e with a wing.
- SpaceX makes a high-expansion version of the Falcon 1 engine with 342 s of I_{sp}.
- This one change improves payload by 60.7%.
- Other optimizations possible:
  - Release condition.
  - Delta-V split.
  - Lifting trajectory.
  - Integrated first stage/wing design.

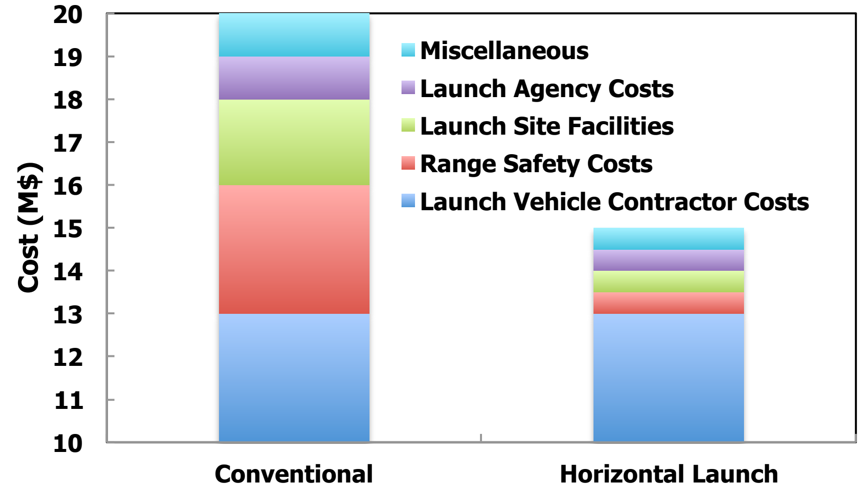
System	Payload (lbm)	Benefit (Δ%)
Falcon 1e	2,200	0%
Falcon 1e – Air Launched	2,749	25.0%
Falcon 1e – Air Launched with altitude nozzle	3,567	60.7%

Source: DARPA/NASA HL Study, 2011

Designing specifically for air launch provides advantages over merely operating there.

DARPA/NASA Study Implications: Using non-conventional ranges reduces costs

- Shipping is avoidable if launch assist aircraft can pick up satellite.
- Launch site facilities are not used and not damaged.
- Range safety process streamlined if zero probability of impact.
- Costs of schedule slippage can exceed cost of entire launch.
- Some costs are unavoidable:
  - Aircraft operations and hangar costs.
  - Damage expectancy calculations/ assurance (treaty-driven).
  - Mission assurance necessary.
  - Deconfliction with air and sea traffic.



Source: Buckley, S, AIAA/Utah State Small Satellite Conference, 2004

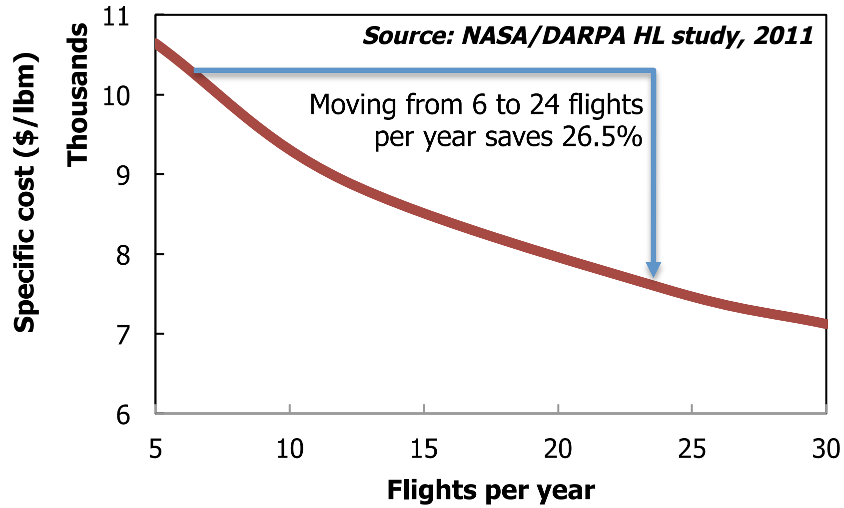
Category	Definition
Launch vehicle contractor costs	The rocket itself
Range safety costs	Direct range costs + range safety process
Launch site facilities	Payload and launch vehicle processing
Launch agency costs	Equipment provided by agency, mission assurance
Miscellaneous	Additional studies, payload adaptors, shipping

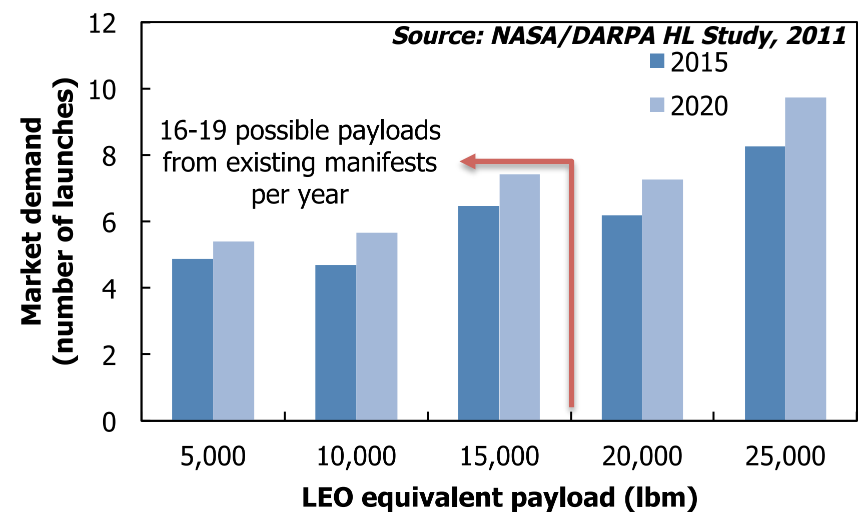
Avoiding most range-related services reduces cost/ pound by up to 25%.

DARPA/NASA Study Results: Flying more often distributes fixed costs over more launches

- NASA/DARPA HL study examined effect of flight rate:
  - Fully burdened cost of operations calculated.
  - Range from 5 to 100 flights per year.
  - Most of the benefit of increased flight rate appears between 6 and 24 flights.
- Sources of possible payloads:
  - Market survey: 16 per year.
  - De-clustering: 12 per year.
  - New small satellites.
- No created demand assumed.
- System offers unique surge capability.
- Demand elasticity is often assumed but has yet to be demonstrated.

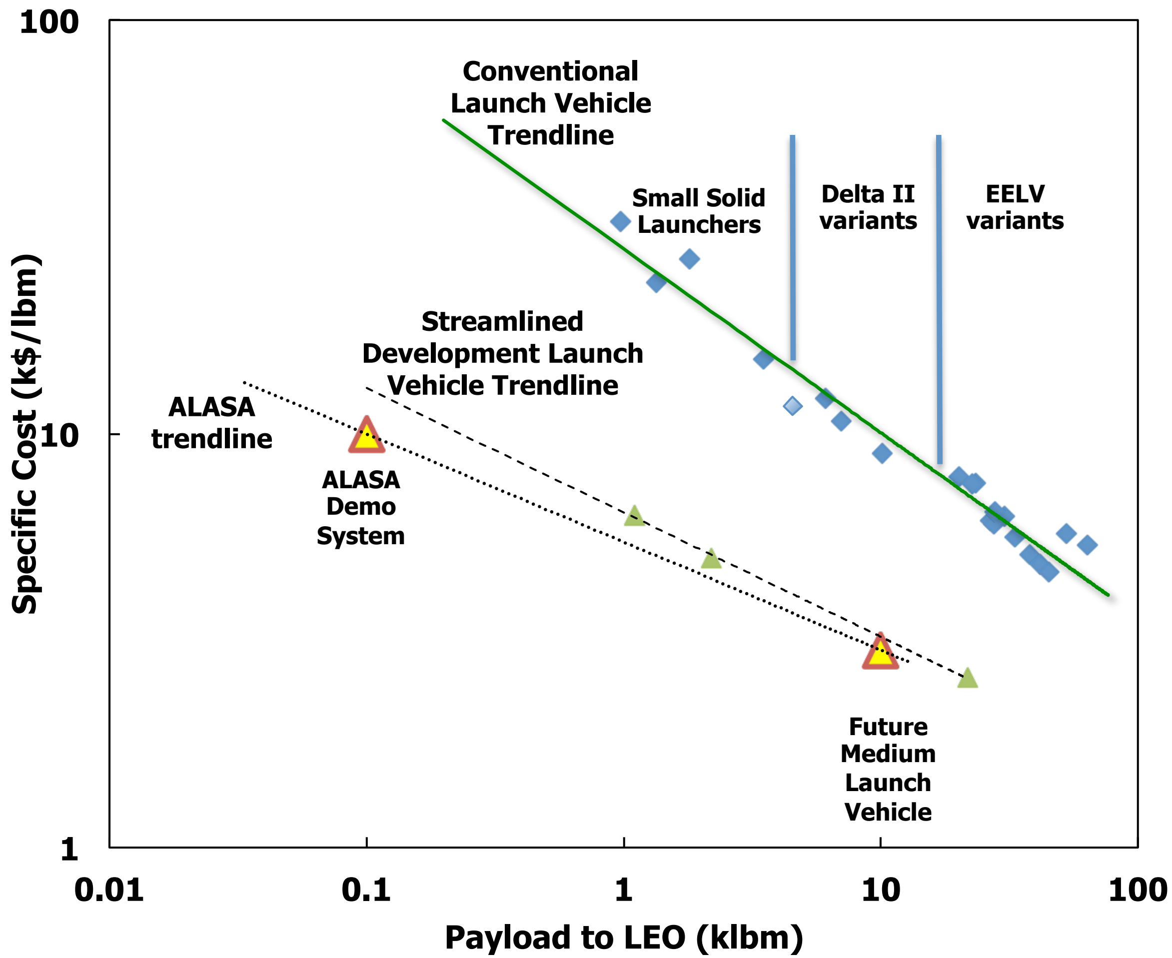
Flying more frequently is essential to spreading fixed costs over many events.





ALASA leads to lower costs/pound to LEO in four independent ways.

- Design for conditions, range avoidance, and frequent operations lead to cost reductions.
- Specific design choices reduce costs further:
  - Aggressive design simplification.
  - Horizontal integration and processing.
  - Small, multi-discipline team.
  - Design for cost and reliability.
- These savings can be pursued in parallel, with realizable benefits for small and medium launch vehicles.



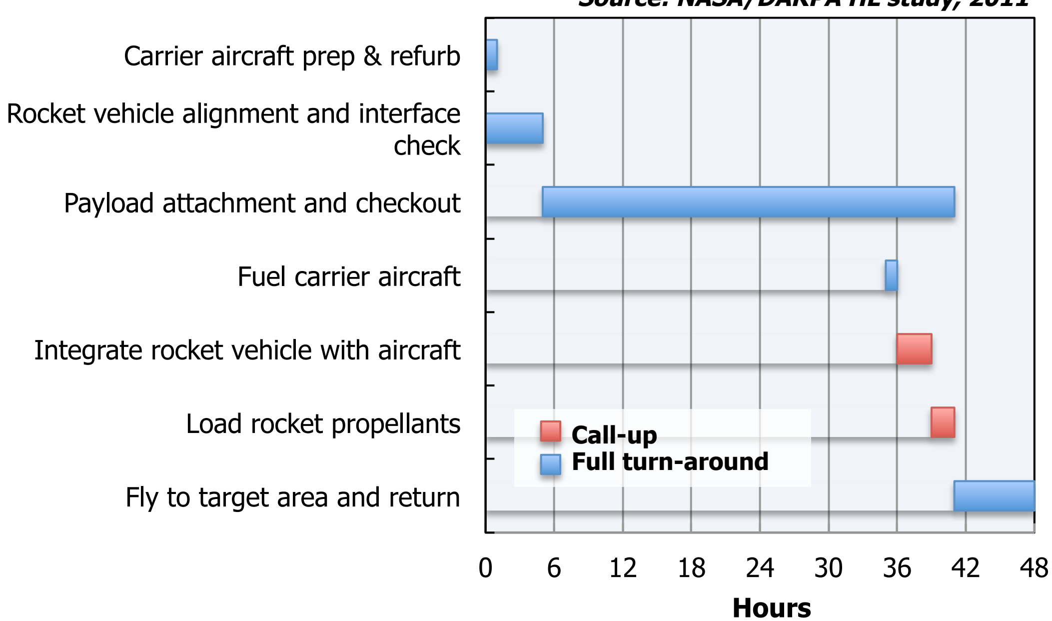
Airborne launch assist improves responsiveness fifteen-fold and reduces uncertainty

Source: BAH Analysis, based on ULA data

System	Payload Integration	Forward base ground operations	Range outages/ weather delay	Additional booster processing	Delay for launch pad clearance	Total time to process
Atlas V	8-9	0	0-5	21	0-45	30-80
Falcon 9	10	0	0-5	20-35	0-60	30-110
Minotaur IV	6	0	0-5	24-39	0-60	30-110
ALASA	***2***	***0-2***	***0***	***0***	***0***	***2-4***

Times in days. Totals for existing systems are minimum figure one-time estimates (not sustainable)

Source: NASA/DARPA HL study, 2011

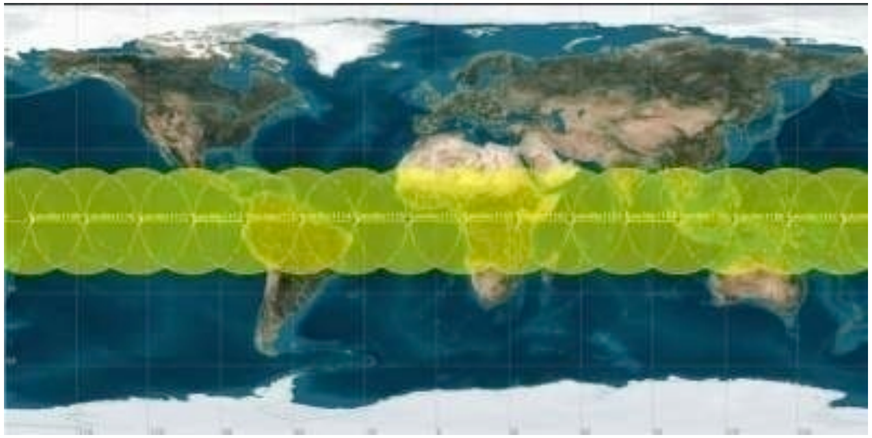


- Assumptions:
  - Payload is on-site and fitted with adapter ring.
  - Not feasible to swap mission of vehicle already in queue (i.e. being processed for next slated launch).
  - Mission of next vehicle in queue does not outweigh COCOM request.
  - A spare mobile launch platform for Atlas is not available.
  - Manning to support "round-the-clock" is available.
  - **Pre-integration of payload with launcher is desirable to achieve < 1 day goal.**

Airborne launch assist improves flexibility, enabling new missions and making existing ones more capable

- Launch opportunities increase.
- The launch assist aircraft is reusable.
- The mission is recallable.
- Weather can be avoided.
- Any runway of adequate length is a potential staging site.
- The launch assist aircraft can serve as the vehicle transporter.
- No conflict with simultaneous launches.
- First-pass overflight from any direction of any place in the world.

24x7 equatorial area coverage is affordable with launch point offset.



- Equatorial launch of satellites improves payload by removing costly plane change maneuver.
- Polar launch of sun-synchronous satellites improves payload due to reduced need to fly against the earth's rotation.

Launch point offset creates strategic surprise.

Airborne launch assist improves resilience of space launch architecture

- The gateway to space is predominately through two fixed locations.
- These locations require repair and refurbishment every time they are used.
- Ample precedent exists for making critical security capabilities re-locatable.
- Catastrophic weather and geologic events cannot be predicted.
- Even common weather events can shut down access to space.

- "(We must seek)…reduced vulnerability of relying solely on fixed launch sites and downrange sites by using more space-based capabilities and transportable systems."

  – National Security Space Plan, 3 May 2010

Launch point offset and ability to relocate prevent strategic surprise.

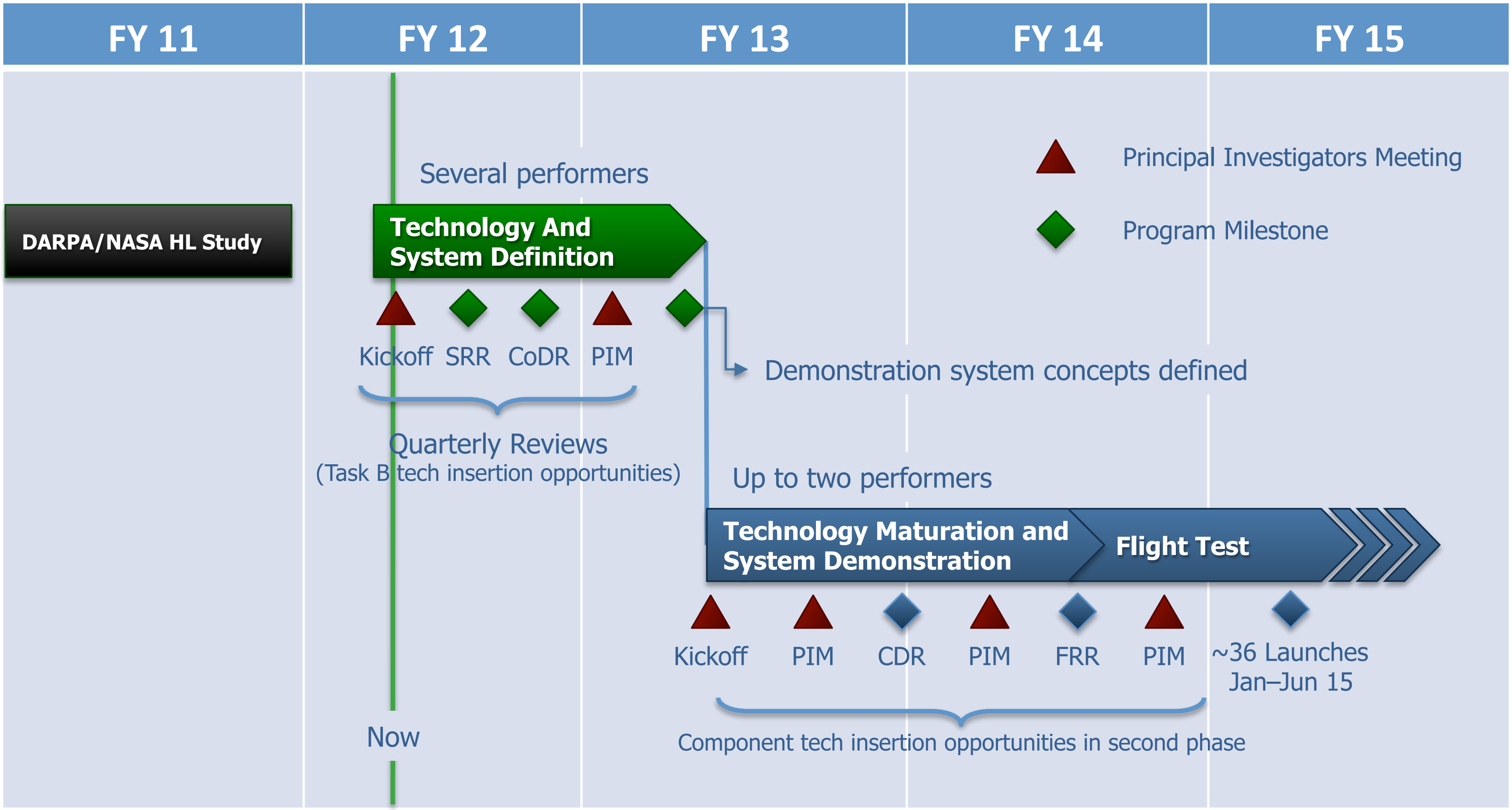
The ALASA demonstration program moves from the status quo to show the full benefit of airborne launch assist

- Demonstrator system faces technical challenges in two main areas:
  - Technology and system definition:
    - Launch vehicle separation issues.
    - Design to hard gross weight limit.
    - Preserving high payload fraction at small scale.
    - Control of weight and margin in an unexplored corner of the design space.
  - Enabling and enhancing technologies:
    - Development of alternatives to current range processes.
    - Handling cryogens in the airborne flight environment if appropriate.
    - Rapid mission planning and execution.
- DARPA/NASA HL study assessed the impact of many enhancing technologies:
  - Up to 38.6% improvement in payload, mostly with associated cost savings.
  - Handling bulk cryogens in the air key to two high-payoff technologies.

Source: DARPA/NASA HL Study, 2011

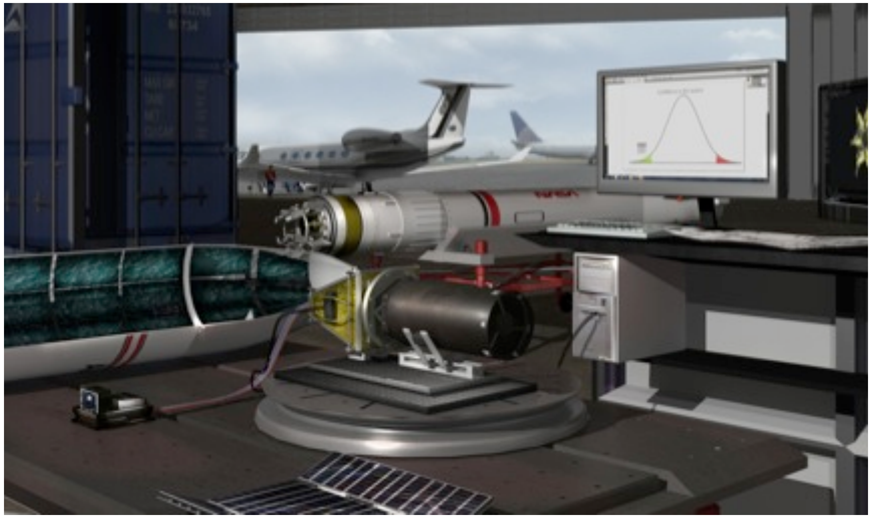
Enhancing Technology	Payload increase (%)	Cost increase (%)
Airborne Propellant Manufacture	35.1%	-17.8%
Airborne Propellant Loading	36.1%	-20.4%
Improved Hydrocarbon Fuel	38.6%	21.2%
Improved RP Engine	24.4%	-8.5%
Al-Li Alloy 2050 Tanks	4.6%	-2.0%

Schedule


FY 11
FY 12
FY 13
FY 14
FY 15
Principal Investigators Meeting
Program Milestone
Several performers
DARPA/NASA HL Study
Technology And System Definition
Kickoff
SRR
CoDR
PIM
Demonstration system concepts defined
Quarterly Reviews
(Task B tech insertion opportunities)
Up to two performers
Technology Maturation and System Demonstration
Flight Test
Kickoff
PIM
CDR
PIM
FRR
PIM
~36 Launches Jan–Jun 15
Now
Component tech insertion opportunities in second phase

There are multiple ways to solve the problem

- The obvious solution:
  - Three stage solid from an F-15.
  - Advantages:
    - Storability.
    - Availability of launch platform.
  - Challenges:
    - Cost engineering.
    - Payload fraction.
- The non-obvious solutions:
  - Liquids.
  - LO_2 manufacture in flight.
  - Novel launch platforms or launch modes.
  - Hybrids, monopropellants, non-cryogenic liquid oxidizers.
  - Innovative launch configurations.
  - Payload-launcher integration.



The Obvious Solution defines the characteristics alternative solutions must have.

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