



DARPA Falcon Program



Small Satellite Study Results

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DARPA/AF Falcon Overview

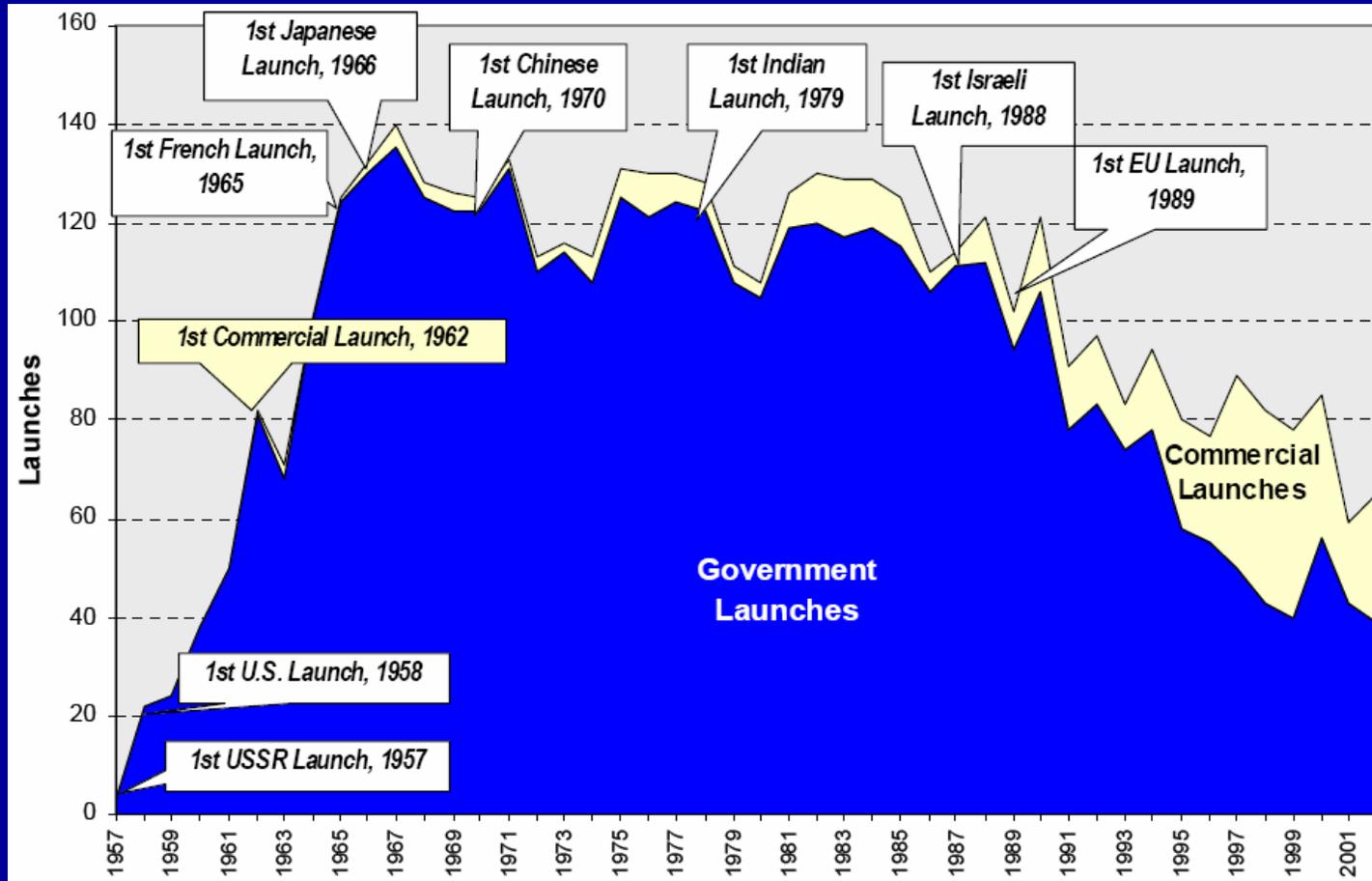


OBJECTIVES of the Small Launch Vehicle (SLV) element -

- Development of responsive, low-cost small launch vehicle(s)
 - Cost of less than \$5M/mission
 - Launching within 48 hours of call up
- Lift 1000 to 2000 lbm payloads to a reference low earth orbit

Associated with the Falcon program was a **Small Satellite study** by AeroAstro Corp and Commercial Space Technologies Ltd (CST)

- Impact vehicle would have on future small satellite development and on U.S. share of the worldwide launch market



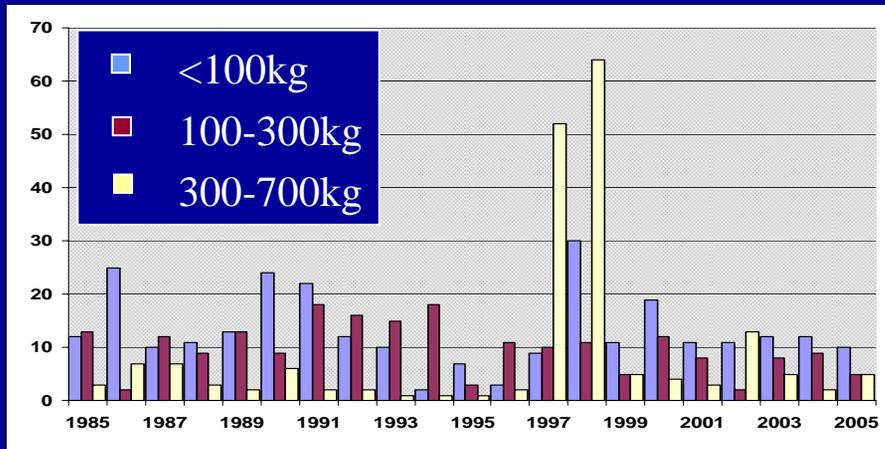
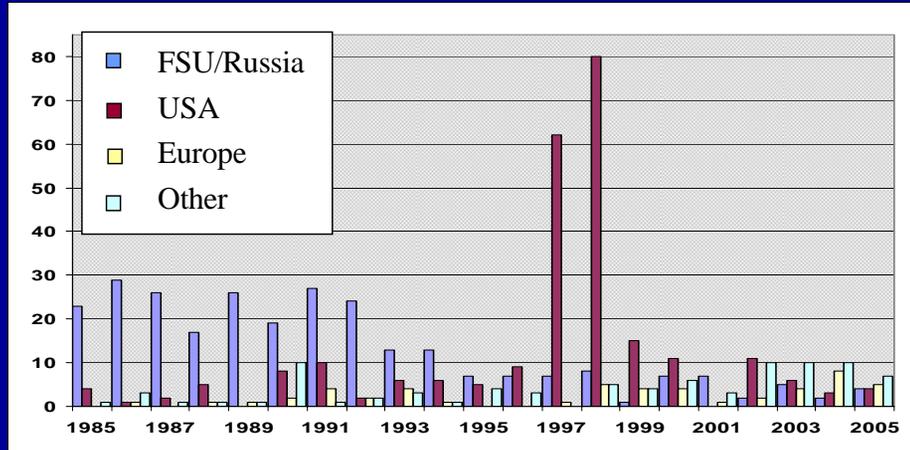
Government has been the primary driver of overall worldwide launches, which have diminished since the peak years of 1967 – 1987. The growing commercial launch market hasn't halted the overall diminishing trend.



Small Sats Launched by Country and Mass



Early on, the Former Soviet Union (FSU) dominated small satellite launches. With the exception of communication constellations (Iridium, Orbcomm and Globalstar) the U.S. share is fairly small over the past 20 years.



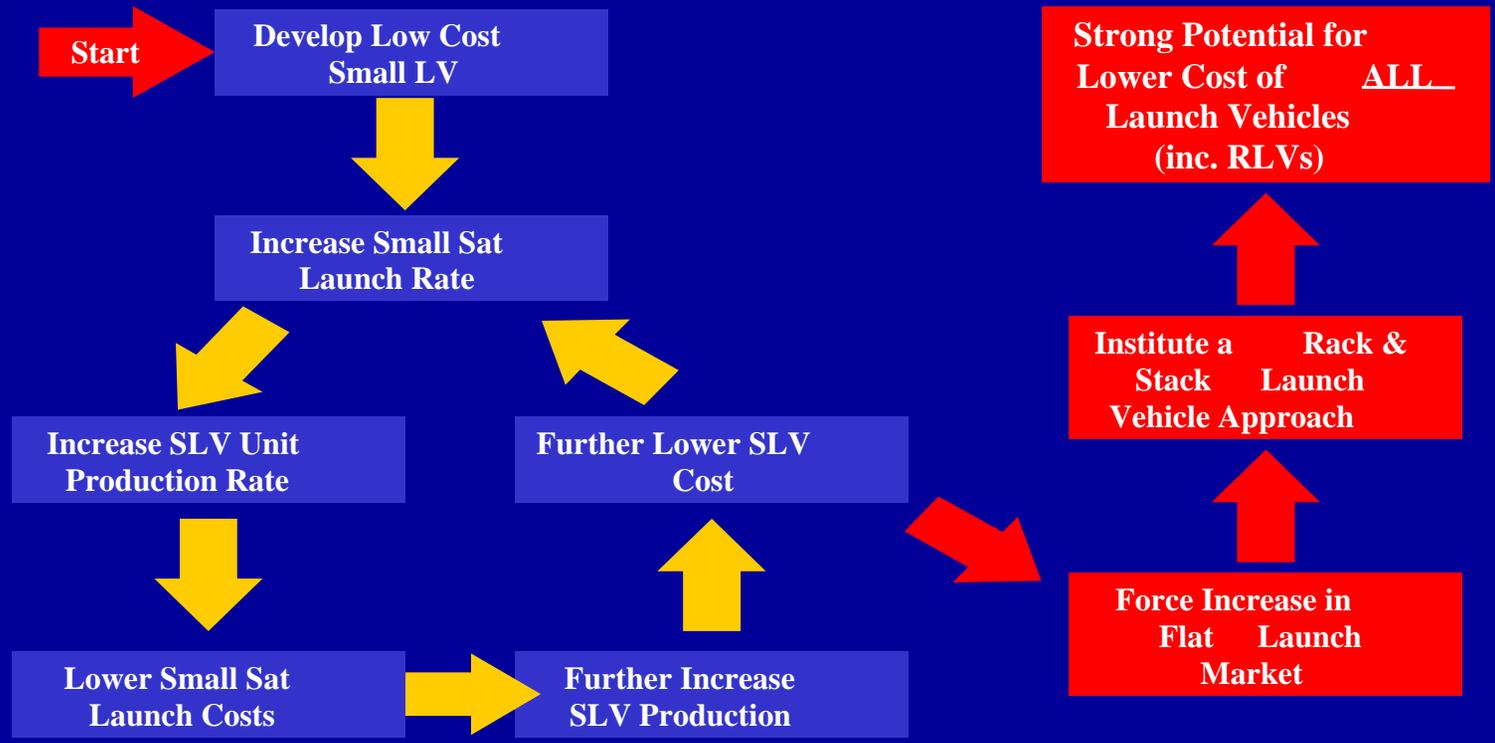
With the exception of communication constellations in the late 1990s the launch rate for small satellites has been fairly flat, with the smaller end dominating the number of launches.



Potential SLV-Small Sat Business Cycle



Hypothesis: As low-cost responsive SLVs are developed and become increasingly available, the small satellite launch rate will increase, giving impetus to increased SLV production rates, which in turn will increase further SLV production and further drive down SLV costs. As this cycle continues, at some point the 'flat launch market' experiences a fairly significant increase aided by a 'rack and stack' launch vehicle approach likely to influence all classes of launch vehicles with resulting lower costs.





Potential SLV-Small Sat Trend



- As SLVs become less expensive (\$5M to \$10M fly away cost) and waits for rides become shorter, **the pervading approach to small satellite development will change.**
- Many small satellites in storage or on the drawing board are unlikely to fly due to cost imbalances between spacecraft and ride to orbit.
 - \$2M to \$5M satellites coupled with a \geq \$25M ride are difficult to insure as well as pass upper management's reasonableness test.
- Low-cost rides allow for **less expensive satellites designed for shorter life on-orbit**, requiring less radiation hardening, protection from other space environmental effects, etc.
- With lower mission costs, **satellite technology to be updated and flown more frequently.**
- Likely to see large sat system designs replaced with **small sat systems.**



Factors for U.S. Low-Cost SLV's Success



1. Optimum payload capability

- Able to satisfy up to a 700 kg (1543.2 lbm) payload capability.

2. Specific launch price, competitive against all methods of launch by other launch vehicles

- Should partially meet factor for price competition with domestic success and perhaps partial success against the less expensive Russian launchers.

3. Availability for launching payloads in world and regional/ domestic markets

- The US low-cost responsive SLV will likely have limited success in ready availability for payloads from anywhere in the world due to International Traffic in Arms Regulations (ITAR) restrictions.



CST Conclusions



1. The **launch rate** for small satellites is **low and flat, remaining so** unless external factors are brought to bear.
2. A U.S. low-cost **SLV** with optimum payload capability, low set price with responsive, available launches **would expand the market by enhancing demand** for launch services.
3. This market expansion will be realized by
 - Small satellite growth with current small satellite development approaches
 - Significant changes in satellite development leveraging the responsive access concept
 - Large-scale small satellite development carrying over to larger satellites and reusable small satellites



Satellite Owner/Manufacturer Interview Results



Mass-

Academics have largest share in <100 lbm (45 kg) spacecraft with many below 10 lbm (4.5 kg) while commercial and military/Government organizations dominate the larger small satellites. Example: Cubesats built by U.S. universities but launched on rockets from Russia and Ukraine.

Desired Orbits-

Interviewees generally preferred high inclination orbits for LEO missions and low inclination orbits for GTO and GEO missions.

Secondary Payload Opportunities-

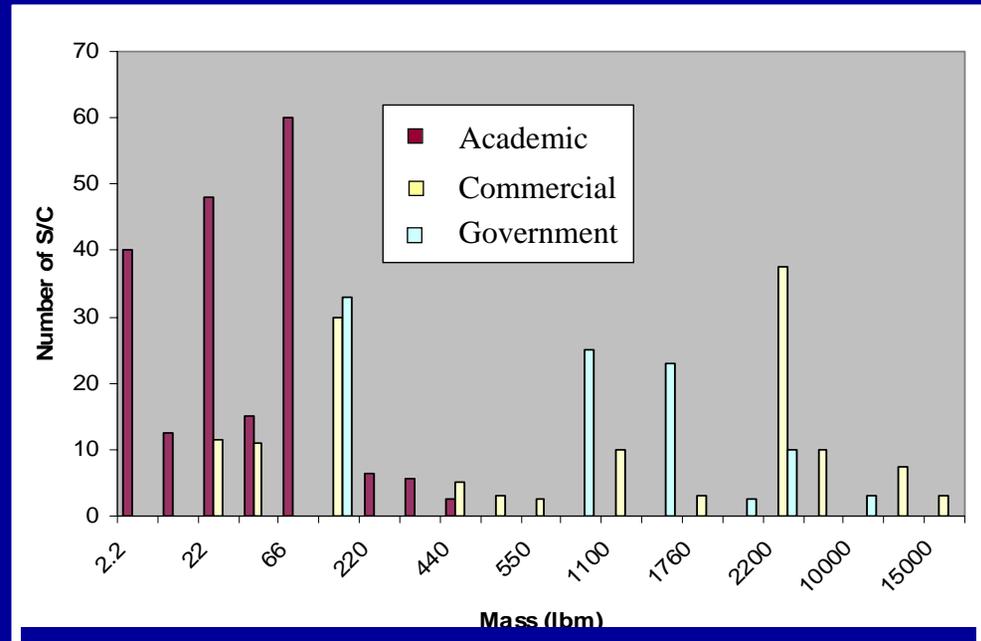
Academic interviewees willing to fly as a secondary payload with several believing only opportunity to get to orbit. The majority of commercial and Government organizations indicated willingness to fly as secondary payloads, especially for their smaller satellites.

Reaction to Proposed Dedicated Low-Cost Launch Vehicle-

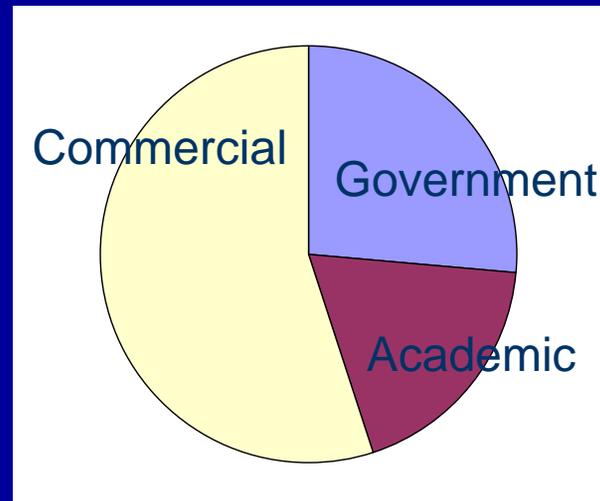
Commercial organizations might plan more missions (additional 2 to 4 per year) but would be driven by market demands. A low-cost U.S. SLV would drive this demand up but several wanted to “wait and see.” Some are operating with understanding that such a vehicle now exists. Some **Government/military organizations** indicated that their planned missions already assume the presence of a U.S. low-cost SLV.

Forecast trends for small satellites (without new fields of applications):

1. Stable level of 25-35 launched satellites/year
2. Stable distribution by mass with 50% light weight, 30% mid weight and 20% heavy weight
3. Domination by ERS and scientific/experimental applications while comm & nav apps shrink
4. Increasing share of commercial launches
5. Worldwide market leaders today are U.S. and Russia but market shares of Europe, Japan, China and others are growing and will eventually equally share the market with the U.S. and with Russia



Does not include AFSPC's estimate of 300+ TacSat launches





Projected Trends for SLV Applications



Assuming the presence of a responsive, low-cost SLV, the following pure commercial concepts were identified:

- Orbital tourism, likely to include orbiting lodging facilities
- Consumer imaging with resolution of one meter; customer would pay \$100 per image through internet connection
- Entertainment involving integration of real space hardware with on line gaming
- Manufacturing and production
- Space burial
- Advertising
- Novelties
- Hazardous waste disposal

Government and Department of Defense concepts identified were:

- Fractionated space using several small satellites performing individually with capability of coordination to work together for synergistic results
- Space control and space situational awareness missions
- Responsive denied area surveillance
- Orbital transportation services for the ISS re-supply/mass download
- Technology validation and qualification in space prior to baselining for major programs
- Universities involving programs such as AFRL's University Nanosatellite Program
- Low-cost dedicated science experiments



Overall Conclusions



The launch rate for small satellites is low and flat, remaining so unless external factors are brought to bear

- **Potential external factor is a U.S. low-cost SLV with optimum payload capability**
 - A low set price with available launches would expand the market by enhancing demand for launch services

Commercial organizations stated that they might plan more missions would be driven by market demands

- Some assume a U.S. low-cost SLV exists while others want to “wait and see” how things pan out. Could see an increase of 2 - 4 launches per year.

Some U.S. Government/military organizations have already assumed a U.S. low-cost SLV in their planning.