Disruptive launch and the shift from a mass to a cost paradigm in satellite communications

IAC-24-B2.8.GTS.3.6

14 October 2024

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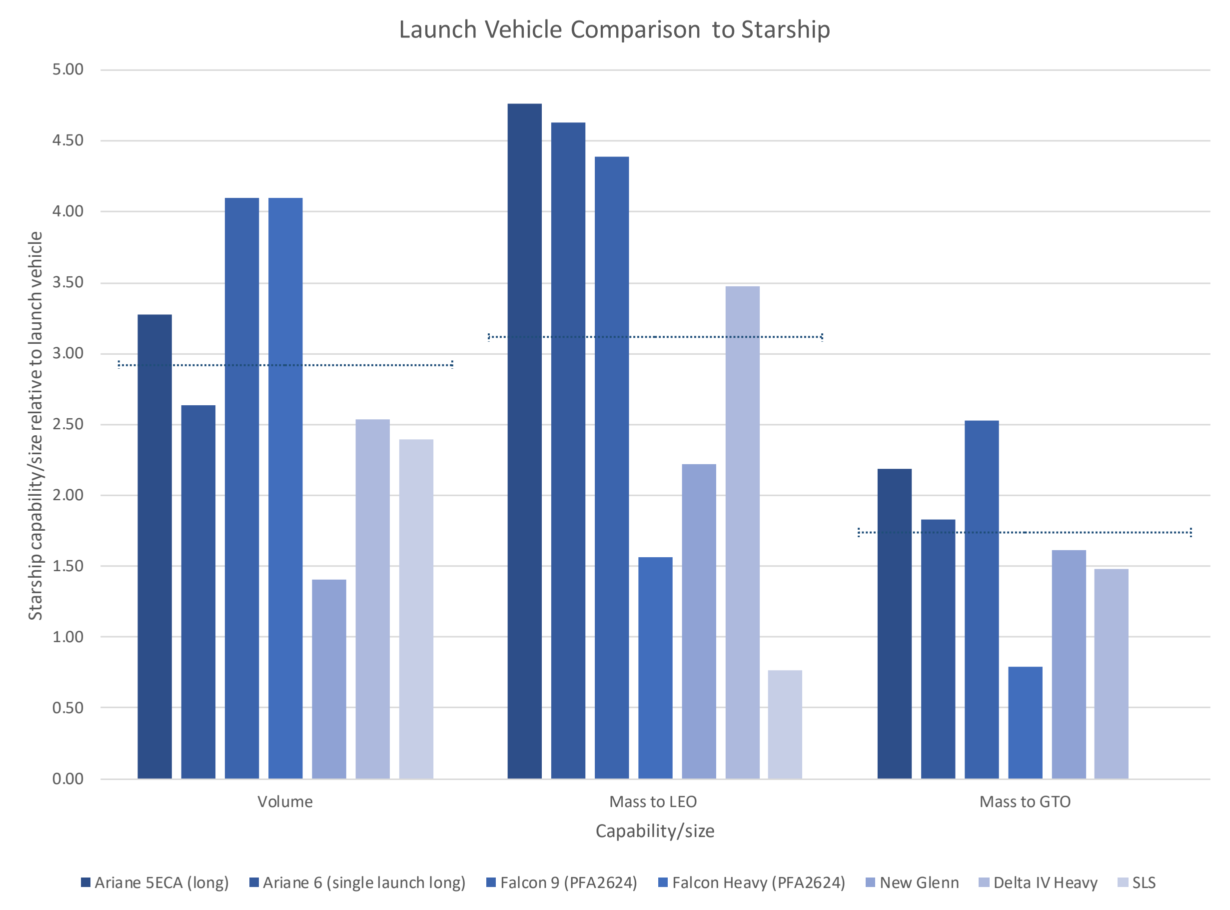
Introduction

SHLVs will disrupt the launch envelope, encouraging a **shift from a volume & mass constrained design philosophy to once focused on cost & performance**. This can open up new markets for satcom.

- High cost of launch has encouraged **mass optimisation** of satellite design
- Limits overall mission costs, but adds complexity & cost to satellite design, and limits performance
- Recent surge in launch vehicle development, including >50t class ("Super Heavy-Lift") with larger fairing
- Starship assessed as most credible SHLV
  - x4 volume & mass increase (vs F9)
  - x2-4 cost improvement ($/kg) (vs F9)



Source: London Economics analysis using various sources

Approach

1 **Quantify magnitude** of SHLV disruption vs current LV benchmark

2 **Assess upstream impact:** cost & subsystem design optimisation

3 **Assess downstream impact** & example use cases: link budget equation

4 **System design:** optimisation for constellation, satellite cost, launch fairing & performance, lifetime (Monte Carlo)

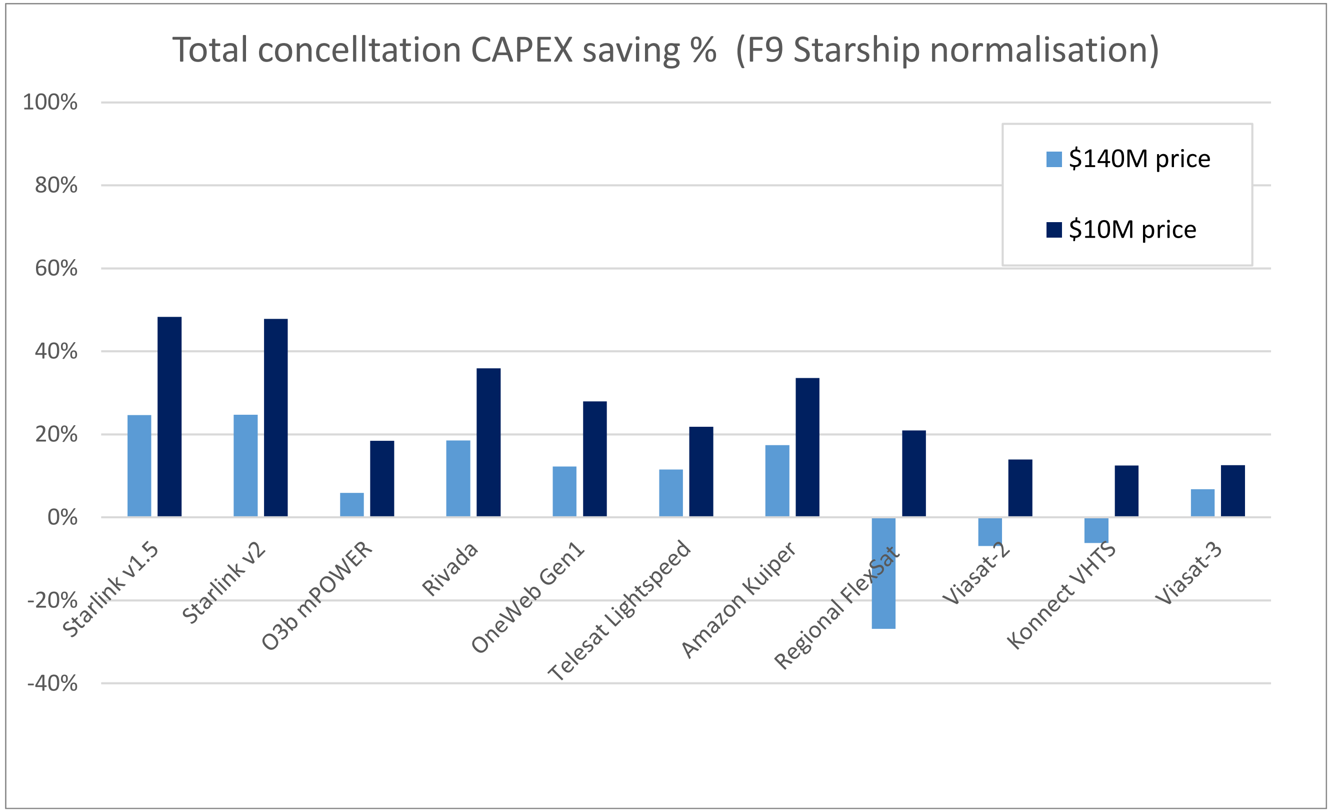
5 **Conclusions & implication:** technology roadmap & wider considerations

Upstream impact (1/2): Retrospective cost analysis

LEO architectures benefit most from SHLVs. Design optimisation required to fully leverage SHLVs.

- CAPEX impact of SHLVs on existing satcom architectures assessed, assuming no design changes
  - Includes satellite design, build, launch, ground segment
  - Each architecture 'standardised' to F9

- Results
  - LEO architectures benefit most
  - Ridesharing a necessity for GEO
  - Average savings with SHLV ~17% (ignoring single GEOs) → design optimisation required to fully utilise benefits of SHLVs



SHLV launch price	LEO	MEO	GEO
$140M	18%	6%	(8%)
$10M	36%	18%	15%

Source: London Economics analysis using various sources

Upstream impact (2/2): subsystem optimisation

SHLVs offer offer opportunity to disrupt traditional “mass-centred paradigm” and focus on cost optimisation of satellite. Suggests scope for cheaper more powerful satcom solutions.

- SHLVs offer relaxation in mass & volume constraints and higher injection orbit
- Each subsystem assessed for potential to reduce costs while maintaining or increasing performance if given more mass budget
- **Result:** potential for cost reductions across various subsystems. Whether these cost savings offset potential increase in marginal launch costs depends on precise launch price.

Subsystem	Cost	Mass / Vol.	Remark
Payload	+	++	Available Performance and Volume most likely will be used for larger, more powerful and complex payloads
Avionics	---	+	Mass manufactured OTS avionics, for example, from automotive sector with additional radiation shielding could replace expensive space qualified avionics. In order to achieve sufficient reliability more redundancy can be used
Attitude & Orbit Control	+	++	Most of the subsystems get cheaper and heavier, the overall spacecraft mass will increase which increases the required Propulsion performance. This can lead to more propellant mass and heavier thruster and more costly and complex propulsion systems
Structure	---	+++	A less mass optimized structure subsystem can lead to strong cost savings, but also strong mass increase
Thermal Control System	+	+	More powerful satcom payloads will require more powerful and costly Thermal control systems
Power	---	++	Cheaper silicone based cells can become the baseline. Furthermore, it needs to be assessed if LiFePo cell batteries can be utilized in S/C

Downstream impact

SHLVs can disrupt the link budget

- SHLVs enables improvements to link budget.
- For example, SHLVs could improve:
  - Satellite power
  - Antenna gain
  - Lowering satellite orbital height (reduce free space losses or adoption of higher frequencies)
- How the increased link performance is leveraged depends on needs of use case. For example, a user could:
  1) Maintain performance and lower cost
  2) Increase link data rates
  3) Reduce SWAP-C of user terminals

Example: Direct-to-Device

- Proposed D2D services prioritise coverage & availability and limited to low bandwidth applications (i.e. emergency messaging).
- Ability to manage very high user densities & millions of simultaneous users also limited.
- Truly “wideband” D2D needs to support 2-5 Mbps for millions of users simultaneously
- SHLVs can increase system link capacity through larger antennas, increased power and lower orbits.

Theoretical system design: "Wideband" D2D

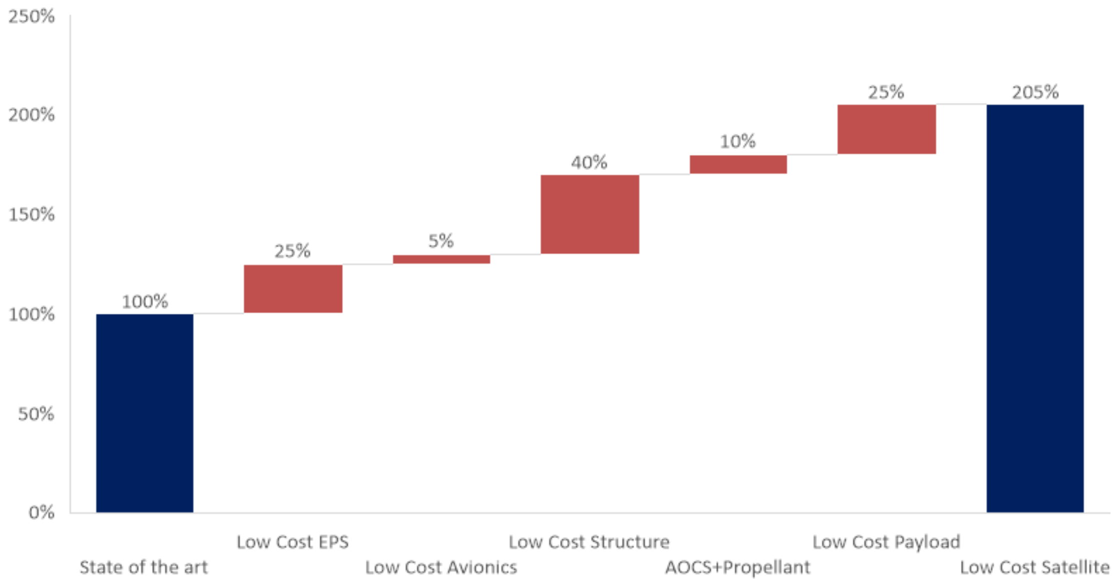
SHLV impact on satellite design is assessed in terms of three optimisations: 1) satellite cost; 2) launch fairing & performance, and 3) lifetime

- A reference architecture is proposed to assess addressability of "wideband" D2D
- **Constellation:**
  - Polar Walker constellation at 1,000km altitude.
  - For global coverage, 220 satellites in 11 planes required
- **Satellite cost optimisation:** mass is 'traded' for cost across all subsystems
- **Launch fairing & performance optimisation:** CAPEX impact of utilizing full fairing & performance of SHLVs
- **Lifetime optimisation:** trade between satellite cost and lifetime to reduce CAPEX/Mbps/month

Results (1/2): satellite cost optimisation

- **Reduction in satellite cost by up to 40% for a doubling in satellite mass** & similar payload performance using low-cost heavy structures and avionics.
- For example, ICs & computers from the automotive sector with heavy radiation shielding. Further cost savings can be achieved using silicon cell-based photo voltaic arrays and low-cost batteries.
- **SHLVs can enable "heavy low cost" satellite designs**

Subsystem mass trend: **mass** increases for each subsystem



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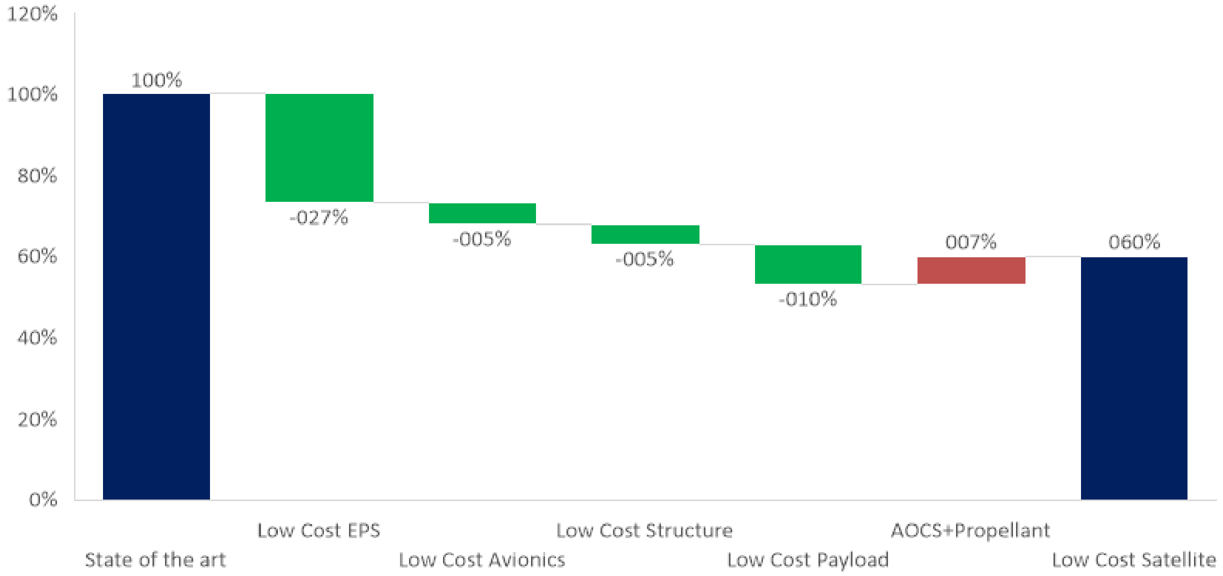
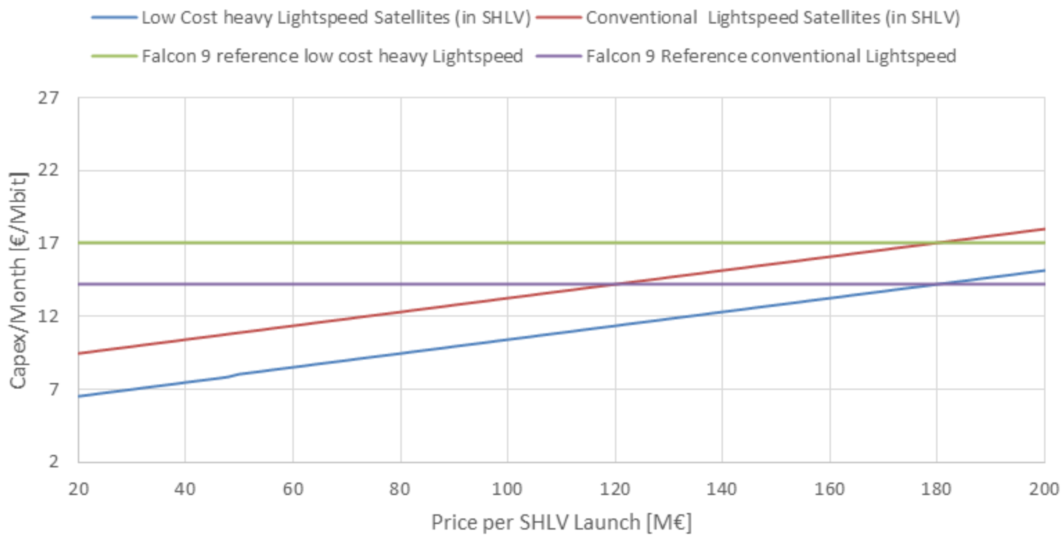
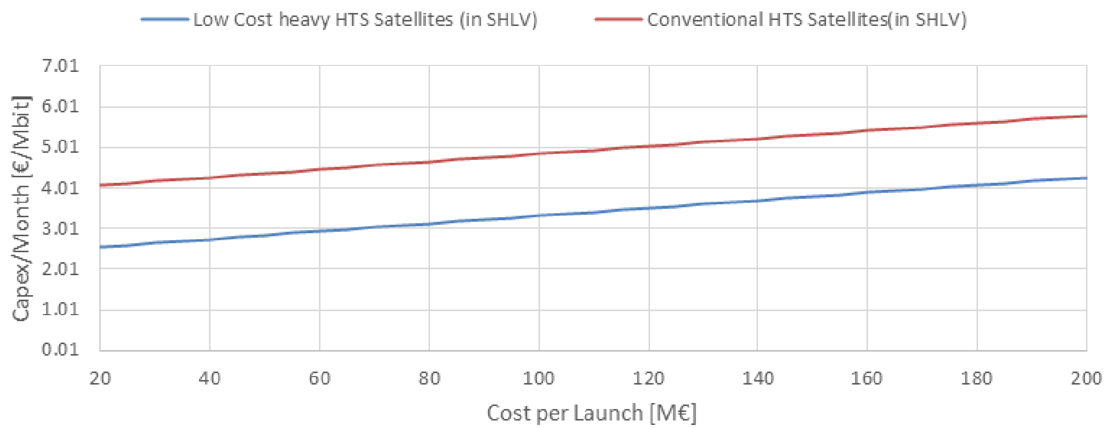


Results (2/2): Monte Carlo analysis

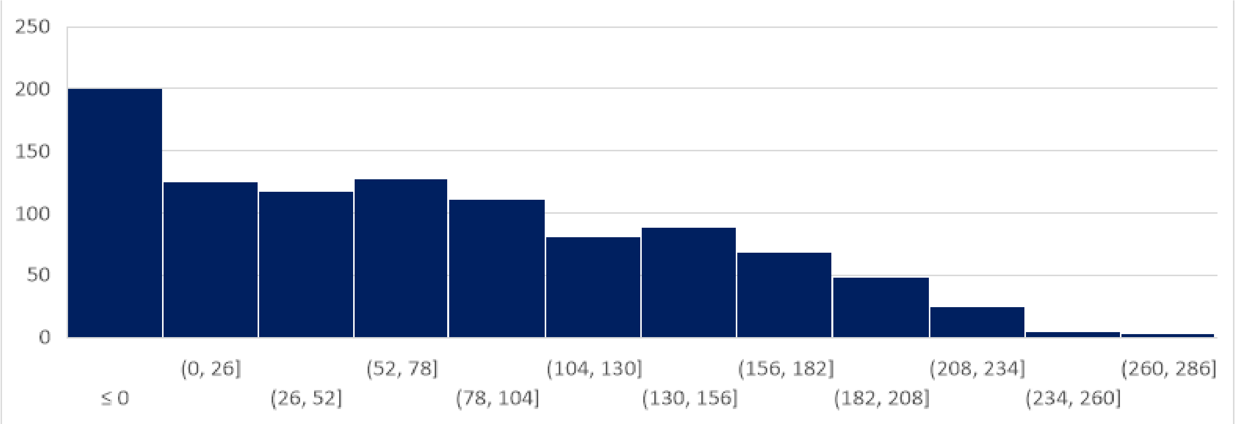
D2D Capex/Mbps/month vs SHLV launch costs: "Heavy low cost" vs conventional



D2D Capex/Mbps/month vs SHLV launch costs: fully utilising SHLV fairing with HTS



- Monte Carlo analysis used to generate distribution of potential mass and cost trades.
- "Low cost heavy" architectures more competitive than conventional on either F9 or SHLV when SHLV price <€180M
- Improvements to manufacturing cost outweigh potential mass gain for "Low cost heavy"
- Strong sensitivity between CAPEX & lifetime: extra mass endowment from SHLVs should be used to reduce subsystem costs but also maintain or even improve subsystem redundancy



Conclusion

- By relaxing constraints, SHLVs offer chance to **reduce subsystem costs**, and motivates **shift from mass to cost optimization of the system**
- **SHLVs more disruptive for LEOs**, so likely to accelerate adoption of these architectures relative to others
- Further optimisation of system design to leverage fairing & performance improvements can significantly increase bandwidth deployed with each launch and **improve economics (CAPEX/Mbps/month)**
- However, adoption of **“low cost heavy” solutions cannot come at expense of system redundancy** & reduced satellite lifetimes
- **Disposable design philosophies only viable at very low launch prices.**
- Improvements to link budget can enhance use cases, such as “wideband” D2D
- Degree of disruption depends on assumptions of launch price & availability of Starship: **Price ≠ Cost**.
- **Competitive pressure required to translate cheaper costs to cheaper launch prices for customers.**

Implications

- SHLV-enabled system design imply cascading impact across technology stack – **R&D priority should be given to subsystems that offer large cost savings** from incrementally lower mass increases

- Adoption of SHLV-enabled systems challenged by other considerations e.g. insurance, spectrum availability, space sustainability

- **Satcom access to SHLVs and competitive launch market are critical**

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IAC-24-B2.8.GTS.3.6