Mission Options for an Indigenously-Developed Small Satellite Launch Vehicle

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Presentation Outline

- An Introduction to ASRI
- The SAFFIRE Rocket Engine
- The CLV Launch Vehicle
- CLV's Ability to Service the African Market
- Mission Analysis Details
- Low-Inclination Mission Capabilities
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An Introduction to ASRI

Our Mission

To develop the technologies and human capital required to establish a sovereign space launch capability for SA and Africa as a whole

People

- Leadership team: 4 academic staff members
- Engineering team: 4 senior engineers, 7 engineers
- Postgraduate students: 6 PhD, 14 MScEng

Funding

- Grant funding from the Department of Science and Innovation and the University of KwaZulu-Natal

SAFFIRE programme

- Development of liquid rocket engine and launch vehicle technologies

Phoenix programme

- Development of low-altitude sounding rockets

Talent Pipeline programme

- Development of human capital via undergraduate projects and bursary support, as well as internships

STEM outreach

The SAFFIRE Rocket Engine

- Under development to power the CLV smallsat launcher
- Prioritises simplicity and cost-effectiveness over performance
- Ubiquitous, low-cost propellants: liquid oxygen and Jet A-1 kerosene
- Ablative chamber cooling
- Electrically-driven propellant pumps
- Two engine versions: booster and upper stage
- Nominal booster engine performance:
  - Thrust: 27.6 kN
  - Burn time: 163 s
  - Specific impulse: 301 s

Ground Test Configuration

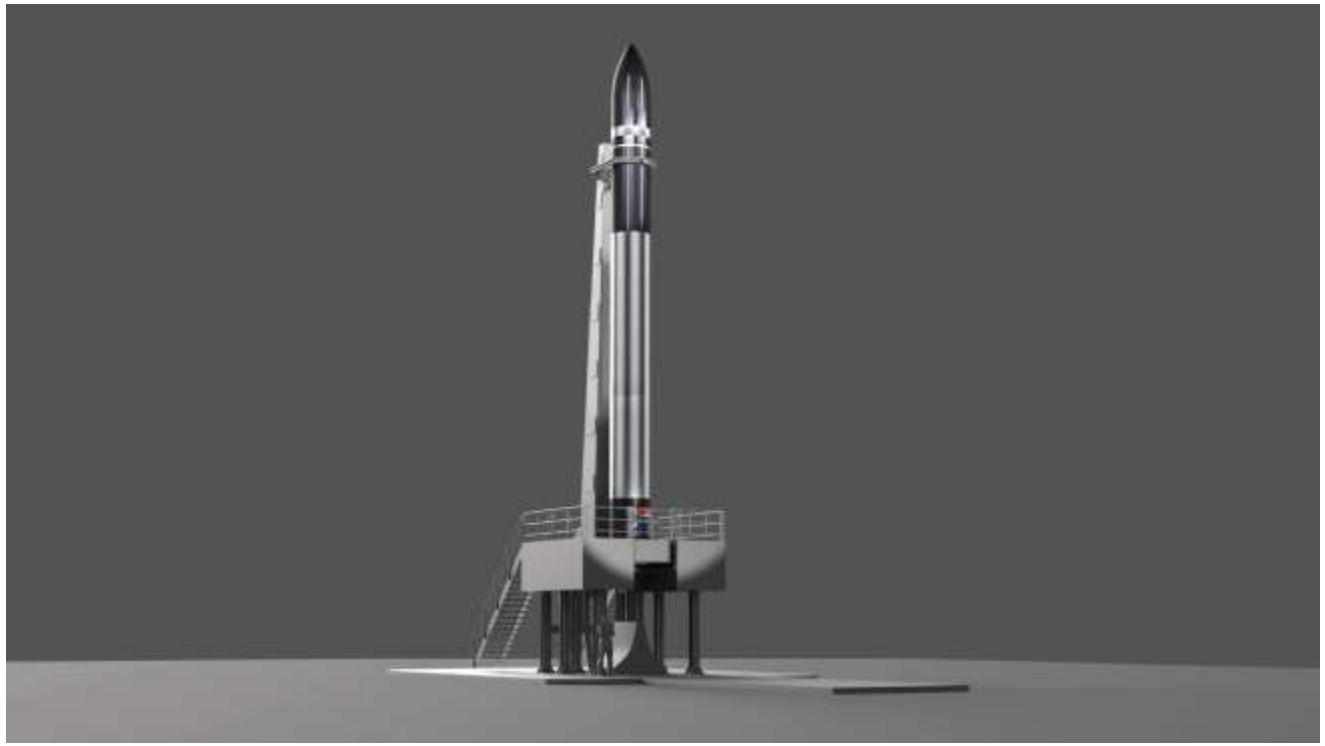
Flight-Weight Configuration

The SAFFIRE Rocket Engine

Testing of the pressure-fed ABLE technology demonstrator engine (November 2021)

The CLV Launch Vehicle

- Two-stage vehicle:
  - Booster stage: 9 SAFFIRE engines
  - Upper stage: 1 SAFFIRE engine
- 19.9 m tall, 1.3 m in diameter, 19.2 tonnes at lift-off
- Design payload capacity: 200 kg to 500 km SSO
- Sized to support the majority of SA's and Africa's future payload needs
- Configured to minimize development time and capital expenditure
- Aligned to SA's manufacturing capabilities



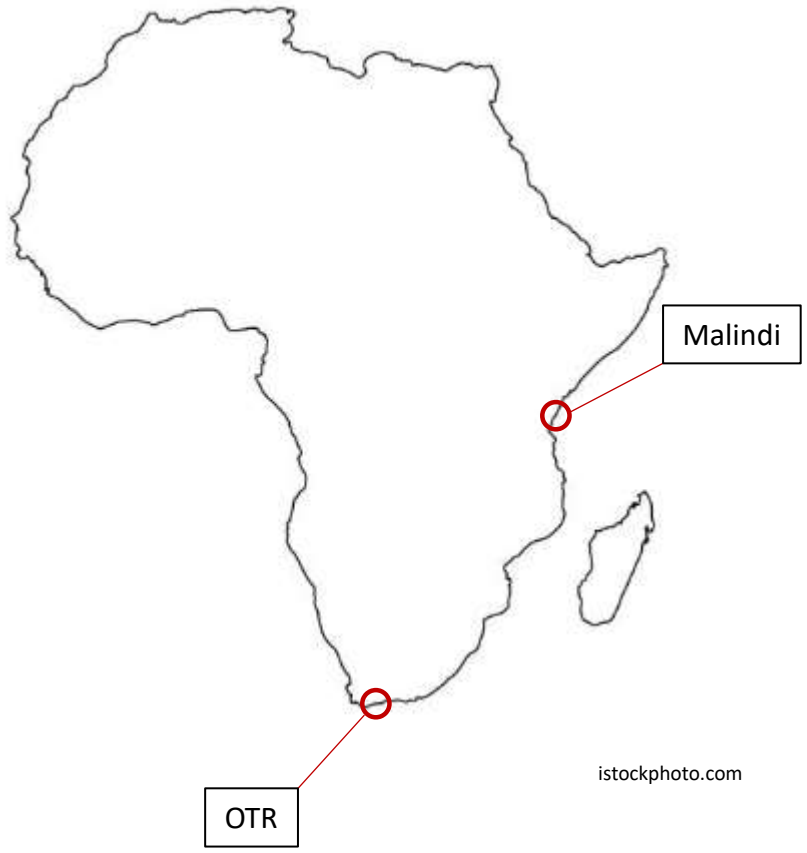
CLV's Ability to Service the African Market

- By ASRI's count, between February 1998 and December 2022, African entities launched:
  - 49 satellites in total
  - 38 satellites to LEO
  - 32 satellites 200 kg or under to LEO
- Based on orbital parameters and CLV's performance envelope, CLV could have launched:
  - 65 % of all African satellites
  - 84 % of Africa's LEO satellites
- With Africa's growing demand for smaller satellites, this level of serviceability will increase significantly with time
- For financial sustainability, the majority of CLV launches in the medium term will need to service international clients

space.com

Mission Analysis Details

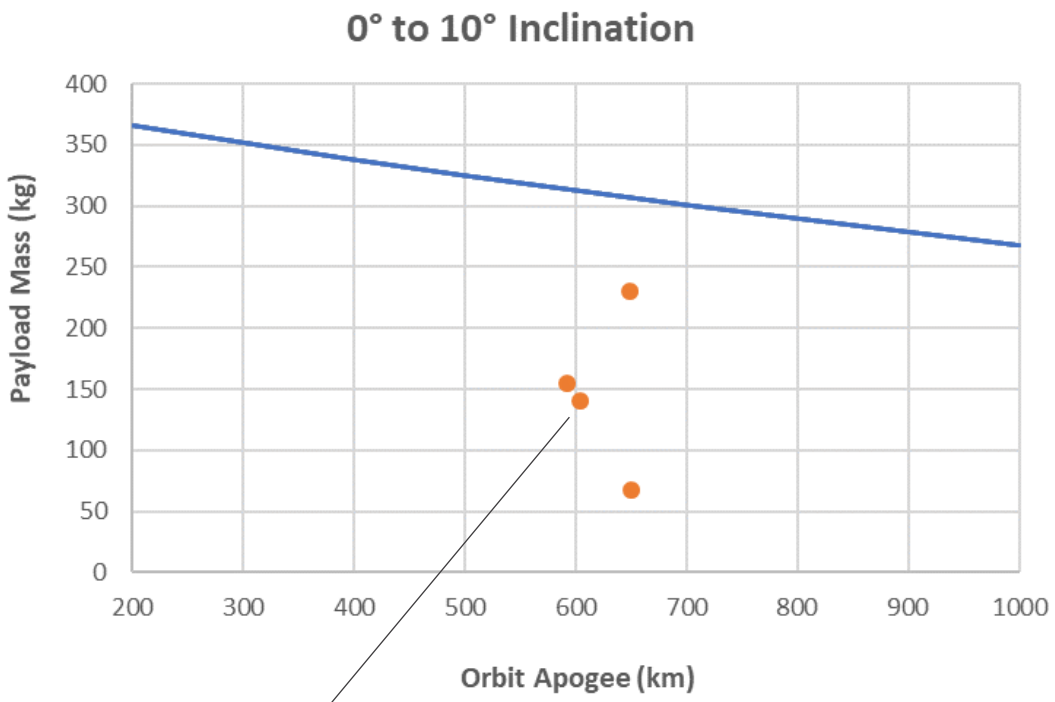
- Launch Site A: Denel Overberg Test Range, South Africa
  - Latitude: 34° S
  - Allocated inclinations: 40° to 100° (without dogleg)
  - Sun-synchronous and mid-inclination missions
- Launch Site B: Malindi, Kenya
  - Hypothetical
  - Latitude: 3° S
  - Allocated inclinations: 0° to 30°
  - Low-inclination missions
- CLV engine performance and subsystem masses derived from ASRI codes
- Payload capacities estimated using an open source tool developed by Launcher



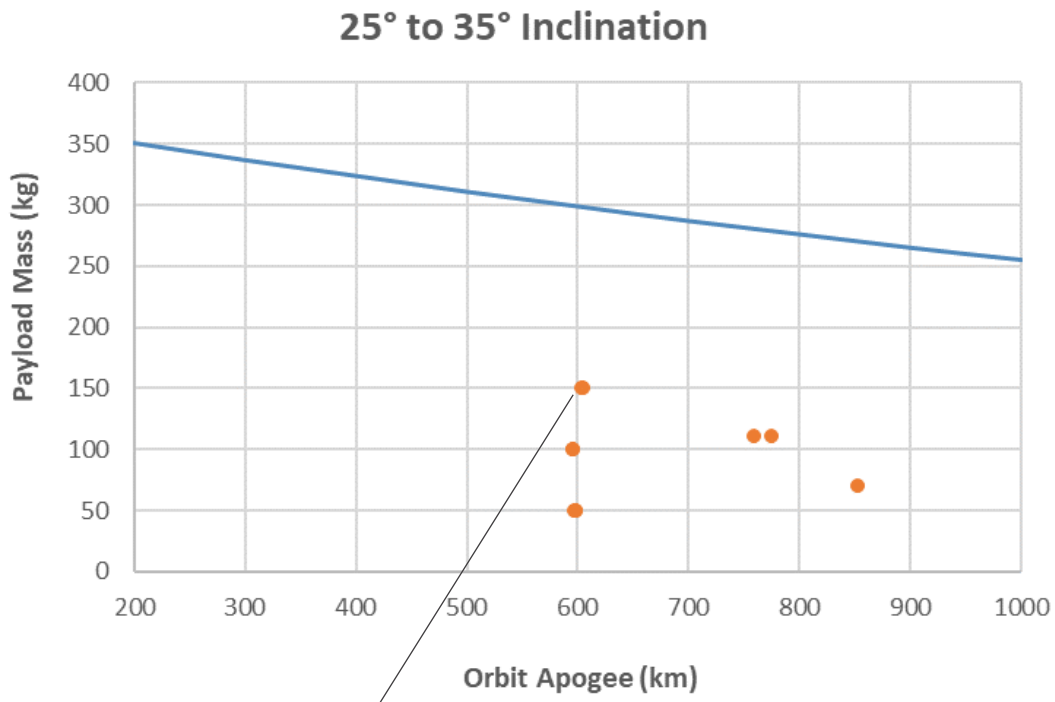
Mission Analysis Details

- Satellite data predominantly sourced from the UCS database
- Circular orbits assumed, defined by apogee altitude
- Filtering criteria:
  - Apogee bounds: 200 km – 1000 km
  - Mass bounds: 50 kg – 250 kg
  - Data timeframe: the last 10 years
  - Starlink and OneWeb satellites excluded
- Number of qualifying satellites: 289
- Inclinations considered:
  - Low-inclinations: 0°-10° & 25°–35° (14 satellites)
  - Mid-inclinations: 42°–48° & 50°–56° (58 satellites)
  - SSO-inclinations: 95°-99° (190 satellites)
- 91 % of qualifying satellites evaluated

Low-Inclination Mission Capabilities



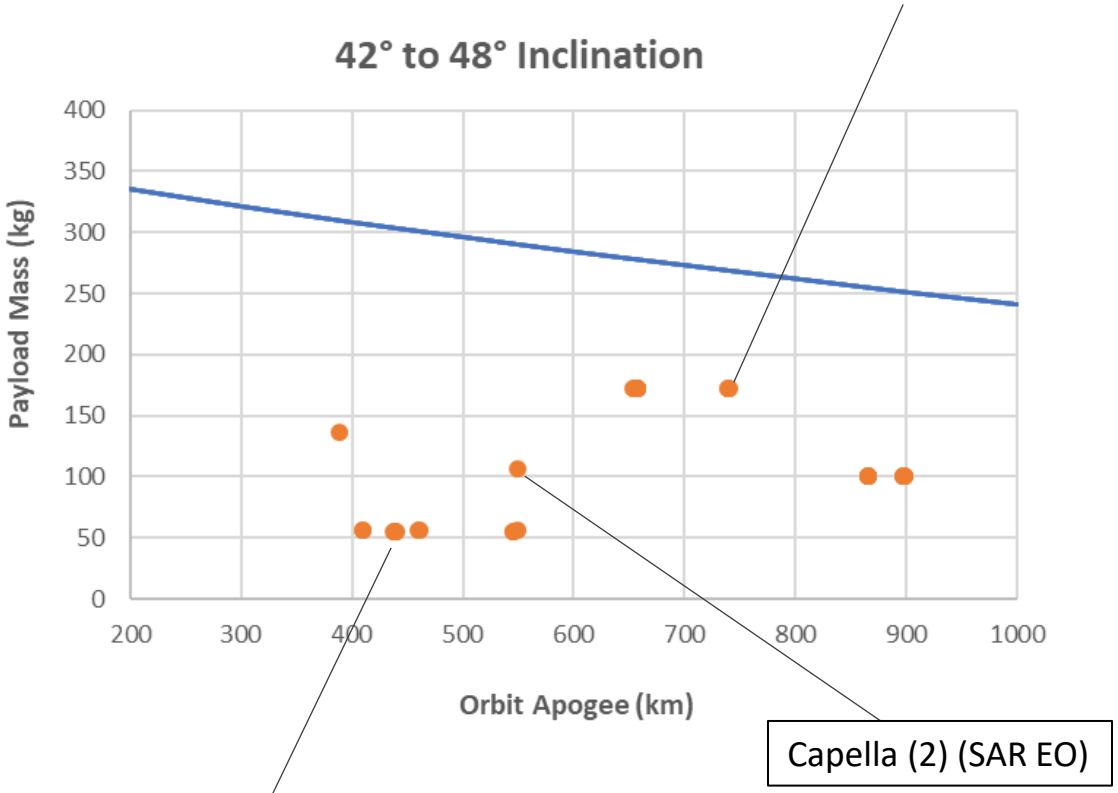
ORS-5 (Optical Surveillance - USAF)



GECAM-A & -B (Space Science - NASA)

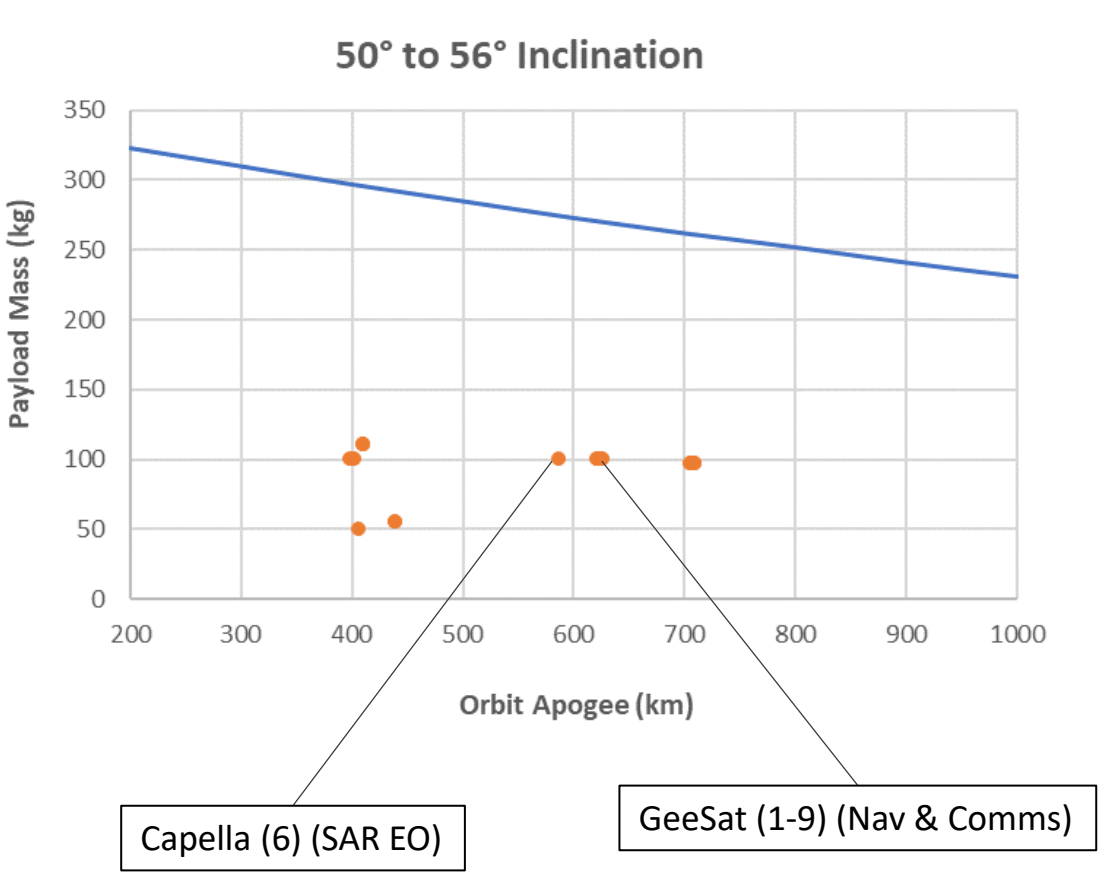
Mid-Inclination Mission Capabilities

ORBCOMM (103) (Comms)



Capella (2) (SAR EO)

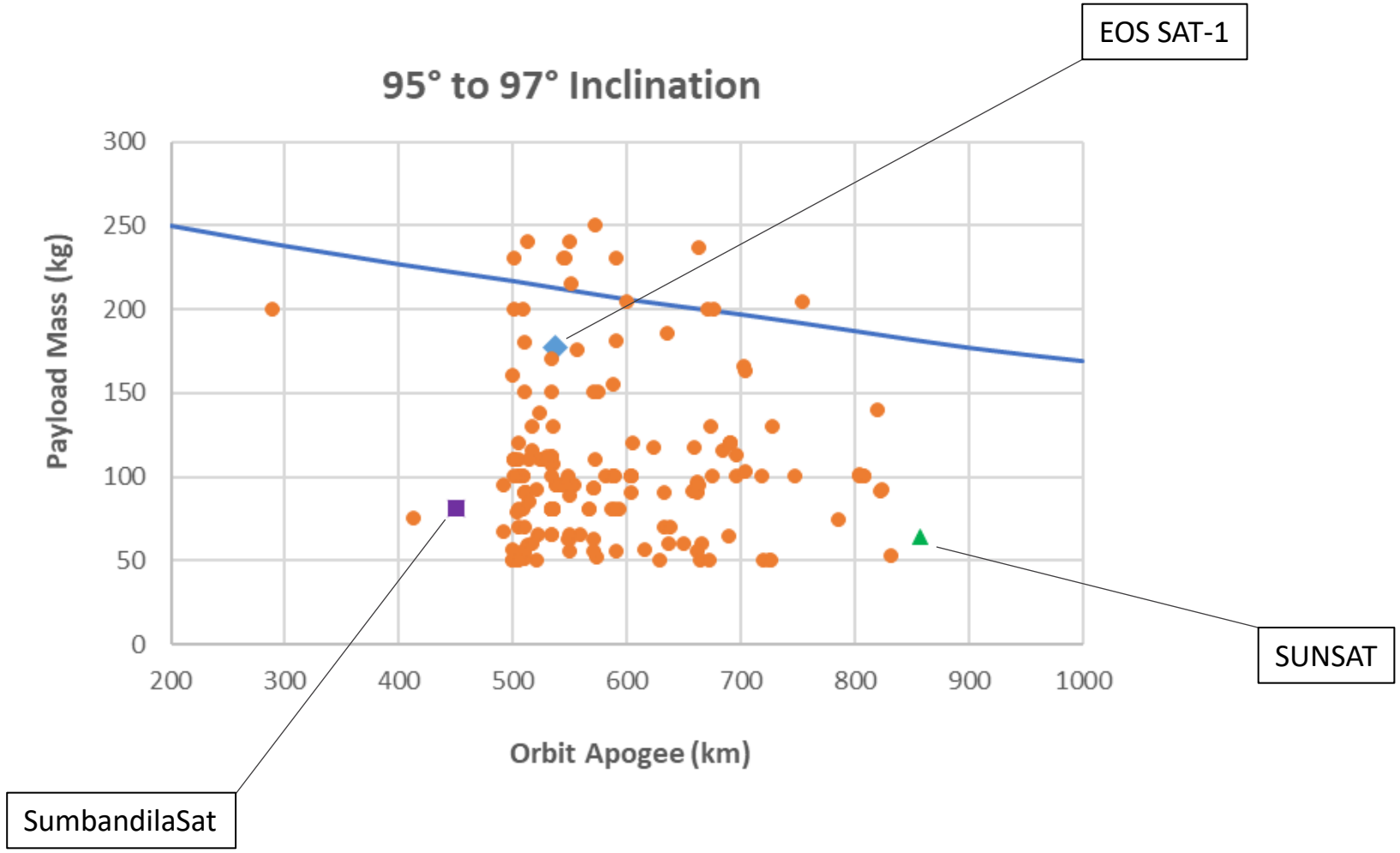
BlackSky Global (14-17) (EO)



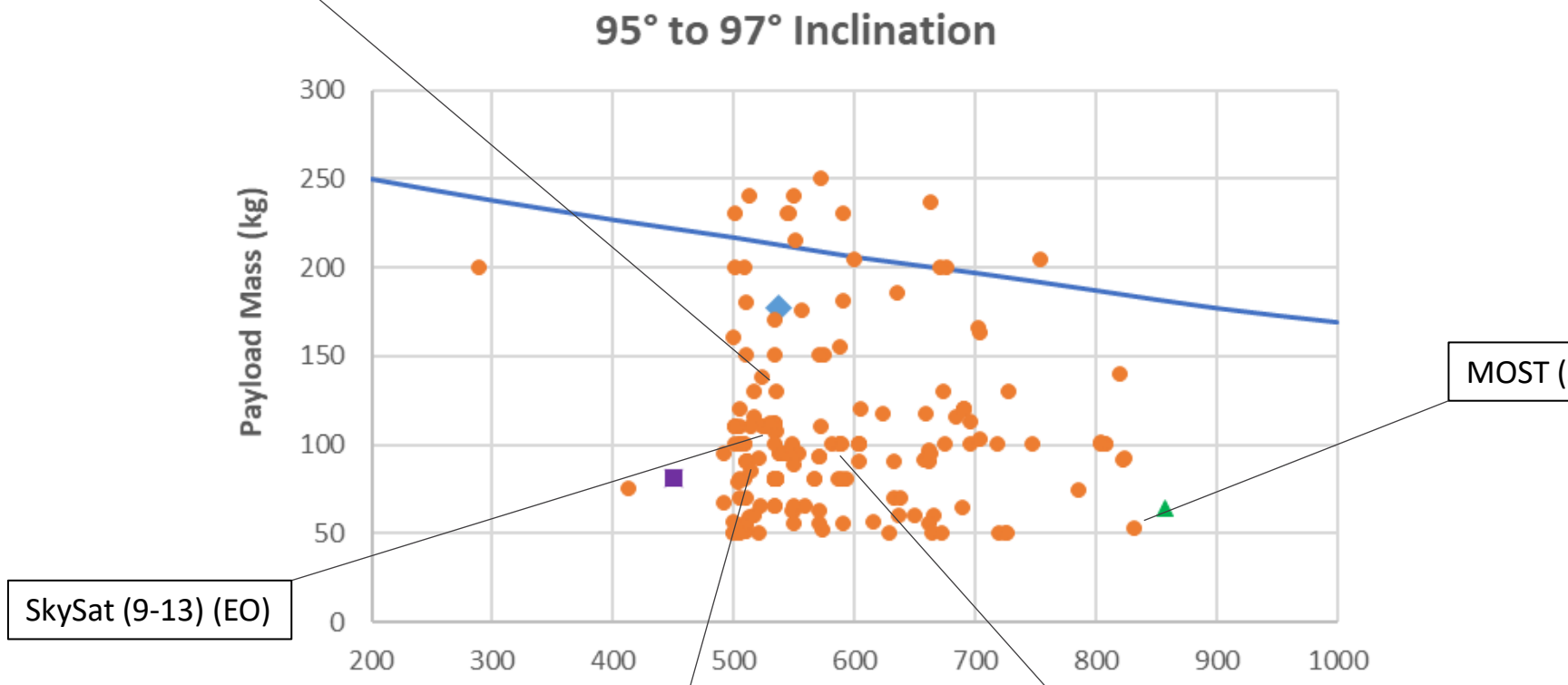
Capella (6) (SAR EO)

GeeSat (1-9) (Nav & Comms)

Sun-Synchronous Mission Capabilities



Sun-Synchronous Mission Capabilities



Athena-Fidus (Military Comms)

MOST (Space Telescope - CSA)

SkySat (9-13) (EO)

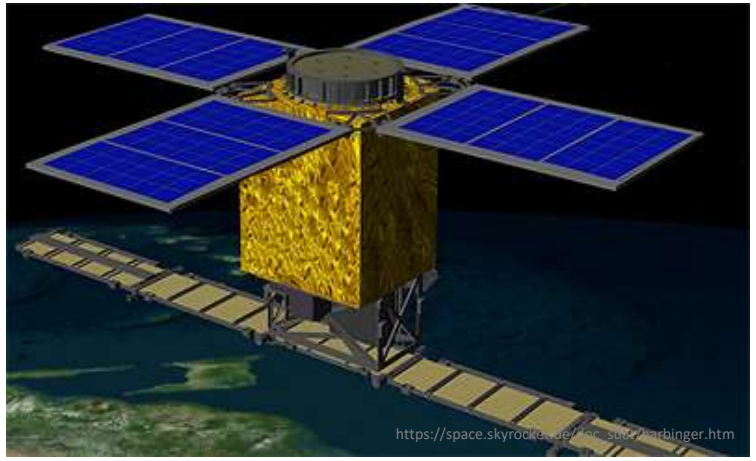
ICEYE (10-20) (SAR EO)

NextSat-1 (Tech Dev - KAIST)

Mission Snapshot: Dual-Mode Surveillance Satellite

Harbinger Dual SAR/Optical Surveillance Satellite

- Aim: To demonstrate the ability of an experimental commercial system to meet US DoD space capability requirements
- Launched in 2019 by the US Army Space and Missile Command
- Launched on a Rocket Lab Electron rocket from Mahia Peninsula, New Zealand
- Includes ICEYE X3 X-band SAR
- Mass: 150 kg
- Orbit: 484 km × 512 km, 40.0°
- Well within CLV's payload capacity



Summary

- The CLV launch vehicle offers the optimal means of providing South Africa and Africa with sovereign space access
- CLV has the capacity to have launched:
  - The majority Africa's past satellite missions
  - The vast majority of international smallsat missions over the past decade (50 kg - 250 kg, 200 km - 1000 km)
- ASRI is moving full steam ahead on the development of the SAFFIRE engine and CLV's building blocks
- Some milestone targets on the horizon:
  - Hot-fire testing of the first ground-test booster engine: Q1 2024
  - Commercial sounding rocket gantry commissioning: Q2/3 2024
  - Hot-fire testing of the first flight-weight booster engine: Q4 2024
  - Flight test of the STEVE sounding rocket (space capable): Q2 2025

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Performance Enhancement Options

- CLV's launch capacity can raised by:
  1. Making vehicle subsystems lighter
     - Tanks: exchanging stainless steel with carbon composites (+ ~5 %)
     - Batteries: performance of COTS Li-ion cells is continuing to improve
     - Regeneratively-cooled combustion chambers are typically lighter than those cooled ablatively
  2. Improving engine performance
     - Regenerative cooling
     - Turbopumps instead of electropumps
  3. Adding a third "kick" stage
- But… How significantly would such enhancements impact:
  - Strategic value? Cost per kilogram launched? Development timeframe and expenditure?

Some Progress Updates

SAFFIRE Engine

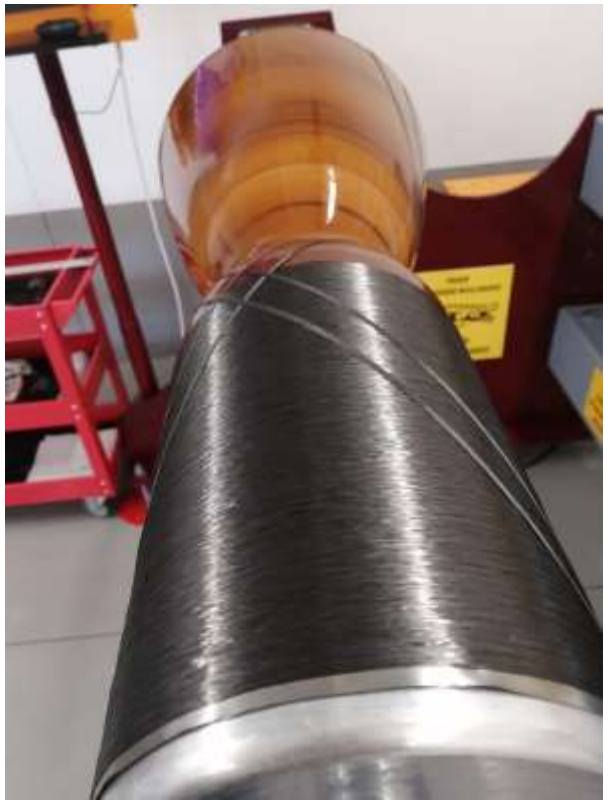
- 3 short-burn combustion chambers complete
- 2 of 3 injector versions complete
- First hot-fire testing expected Q1 2024

Commercial Sounding Rocket Gantry (OTR)

- Tenders submitted for commercial sounding rocket gantry at OTR
- Commissioning expected Q2/3 2024

Permanent Engine Test Facility (OTR)

- ERA approval obtained
- Hardware procurement for phase 1 of permanent engine test facility underway
- Phase 1 completion expected Q2 2024



Some Progress Updates

STEVE Suborbital Rocket

- Composite propellant tank development work underway
- Propellant tank test rig complete

Phoenix Programme

- Development work proceeding on 2 new Phoenix rocket variants
- Working group for flight termination and telemetry systems development formed
- Next flight test campaign at OTR scheduled for Q2/3 2024

ASRI Office Space

- Plans for a brand new office space for ASRI engineering staff and students will be finalised shortly
- Completion expected Q2 2024

Flight testing of the Phoenix-1