TECHNICAL ACTIVITIES OF UKZN'S AEROSPACE SYSTEMS RESEARCH INSTITUTE

Jason Denny

Senior Engineer: Testing and Facilities

Aerospace Systems Research Institute (ASRI)
University of KwaZulu-Natal

An Introduction to the Aerospace Systems Research Institute

Our Mission

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

Our Location

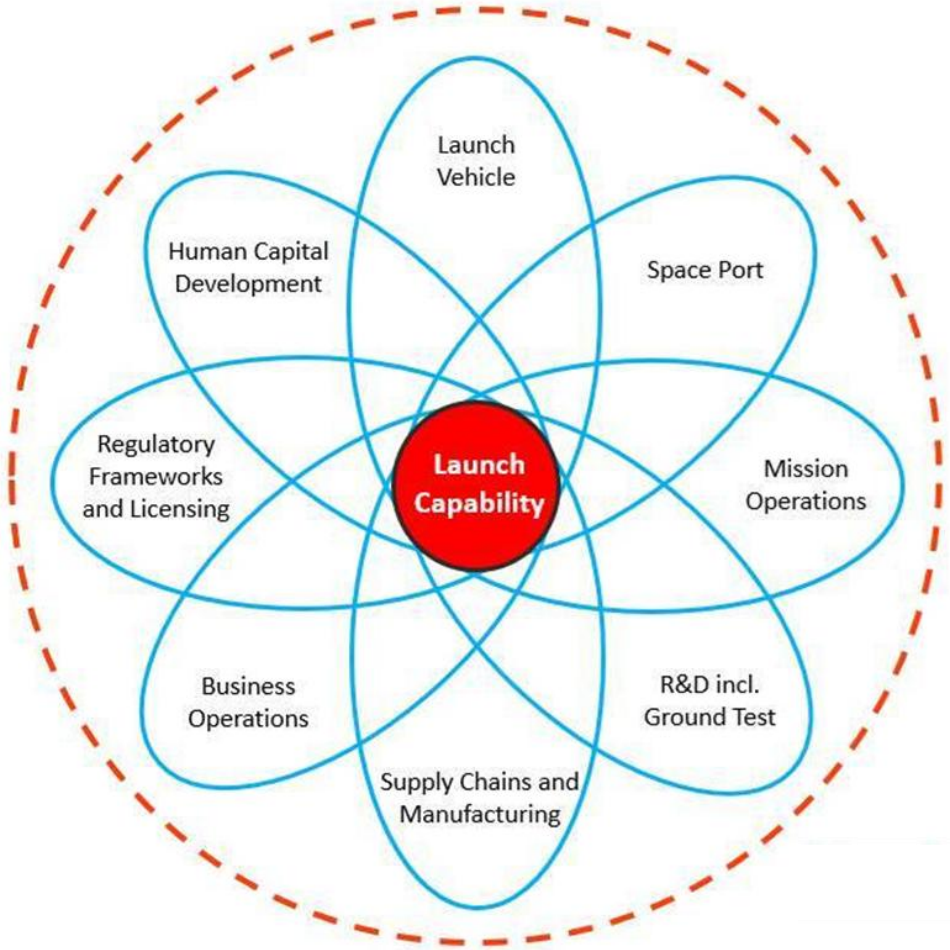
University of KwaZulu-Natal, Durban, South Africa

Our People

- Leadership team: Prof Mike Brooks, Prof Glen Snedden & Prof Jean Pitot (ASRI's Explosive Responsible Person)
- Engineering team: 6 senior engineers, 12 engineers
- Postgraduate and undergraduate students

Our Funders

- RSA Department of Science, Technology and Innovation
- University of KwaZulu-Natal



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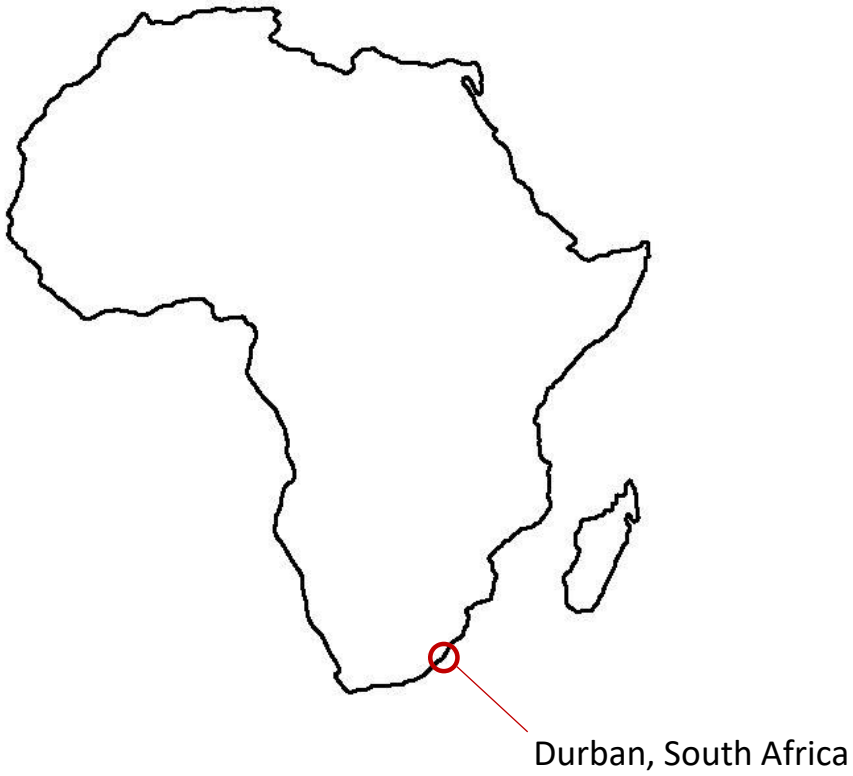

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SAFFIRE Programme

Development of the SAFFIRE liquid rocket engine, the CLV small launch vehicle, and allied technologies

Phoenix Programme

Development of low-altitude hybrid sounding rockets for student training and engineering support

Talent Pipeline Programme

Upskilling and induction of undergraduate engineering students, particularly those from disadvantaged backgrounds

In-Space Propulsion Programme

Development of green propellants and thrusters for satellite and spacecraft propulsion applications

Turbomachinery Research Programme

Gas turbine, turbopump and fan research

SAFFIRE Liquid Rocket Engine

CLV Launch Vehicle

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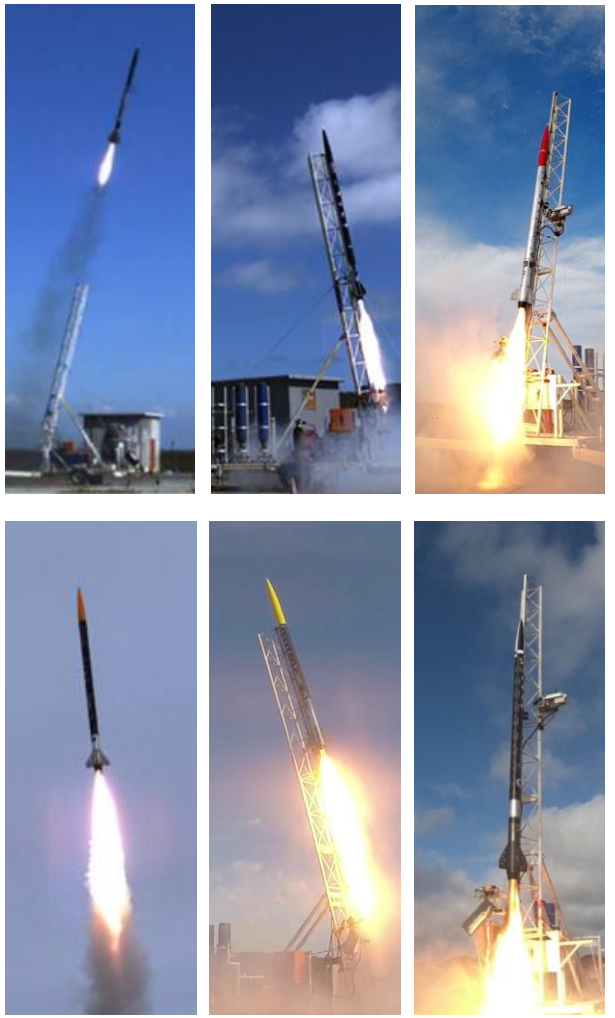

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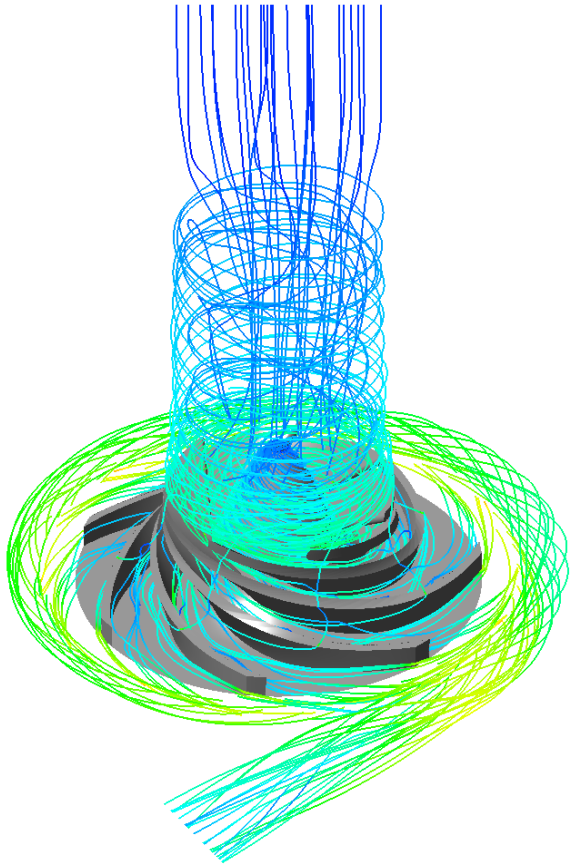
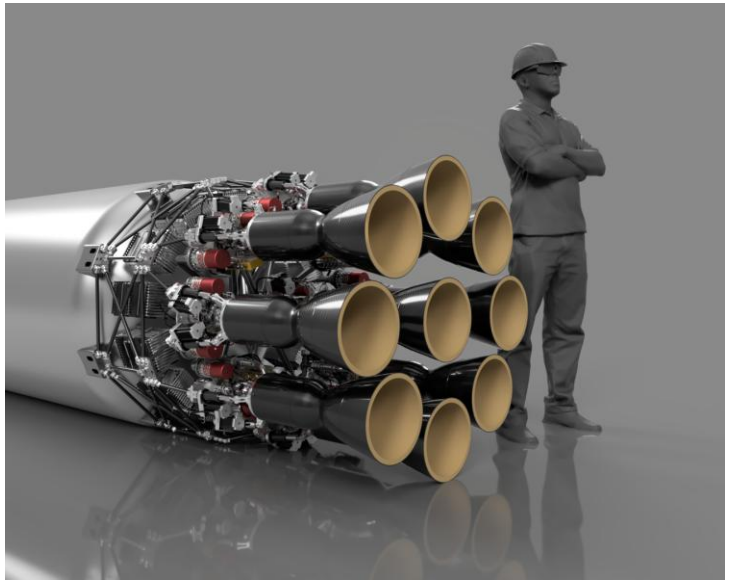


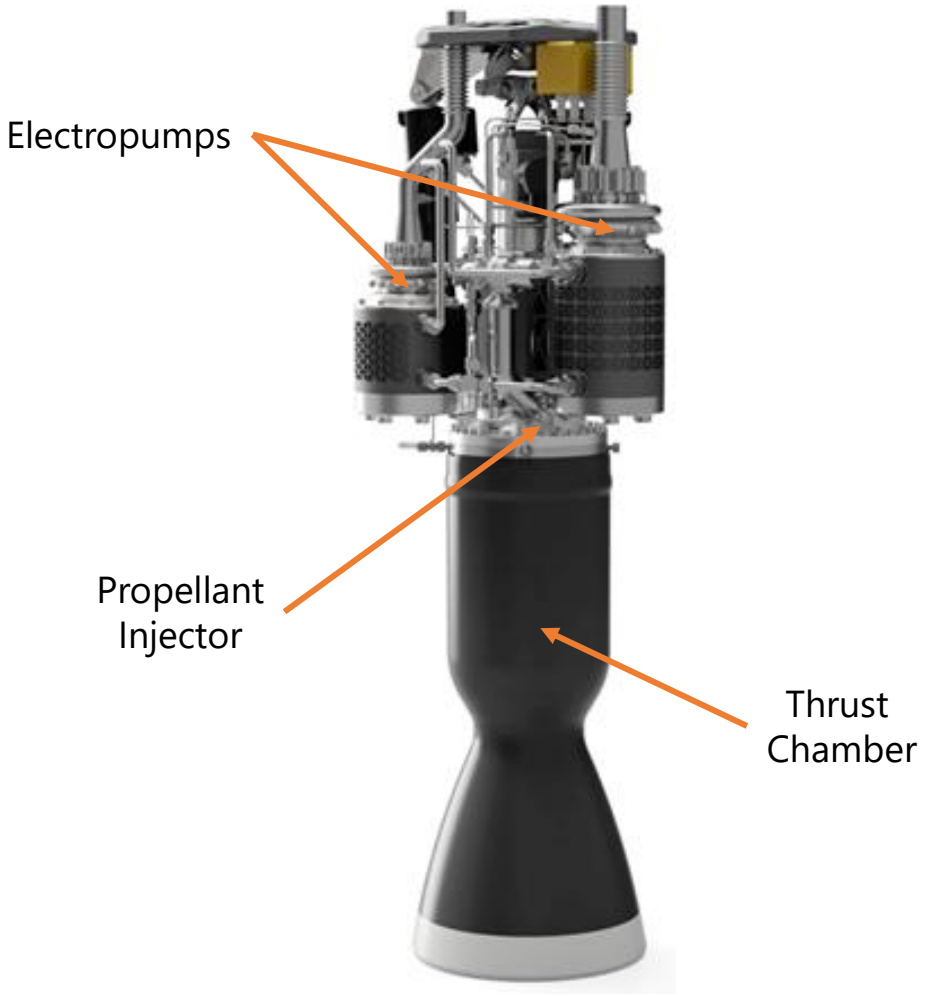
The CLV Small Launch Vehicle Concept

- Configured to minimize development time and capital expenditure
- Technology architecture aligned to SA's manufacturing capabilities
- Baseline design point: 200 kg to 500 km SSO
- Height: 19.9 m tall, diameter: 1.3 m, GLOM: 19.2 tonnes
- Propellants: liquid oxygen/kerosene
- 9+1 SAFFIRE engines
- Container transportable



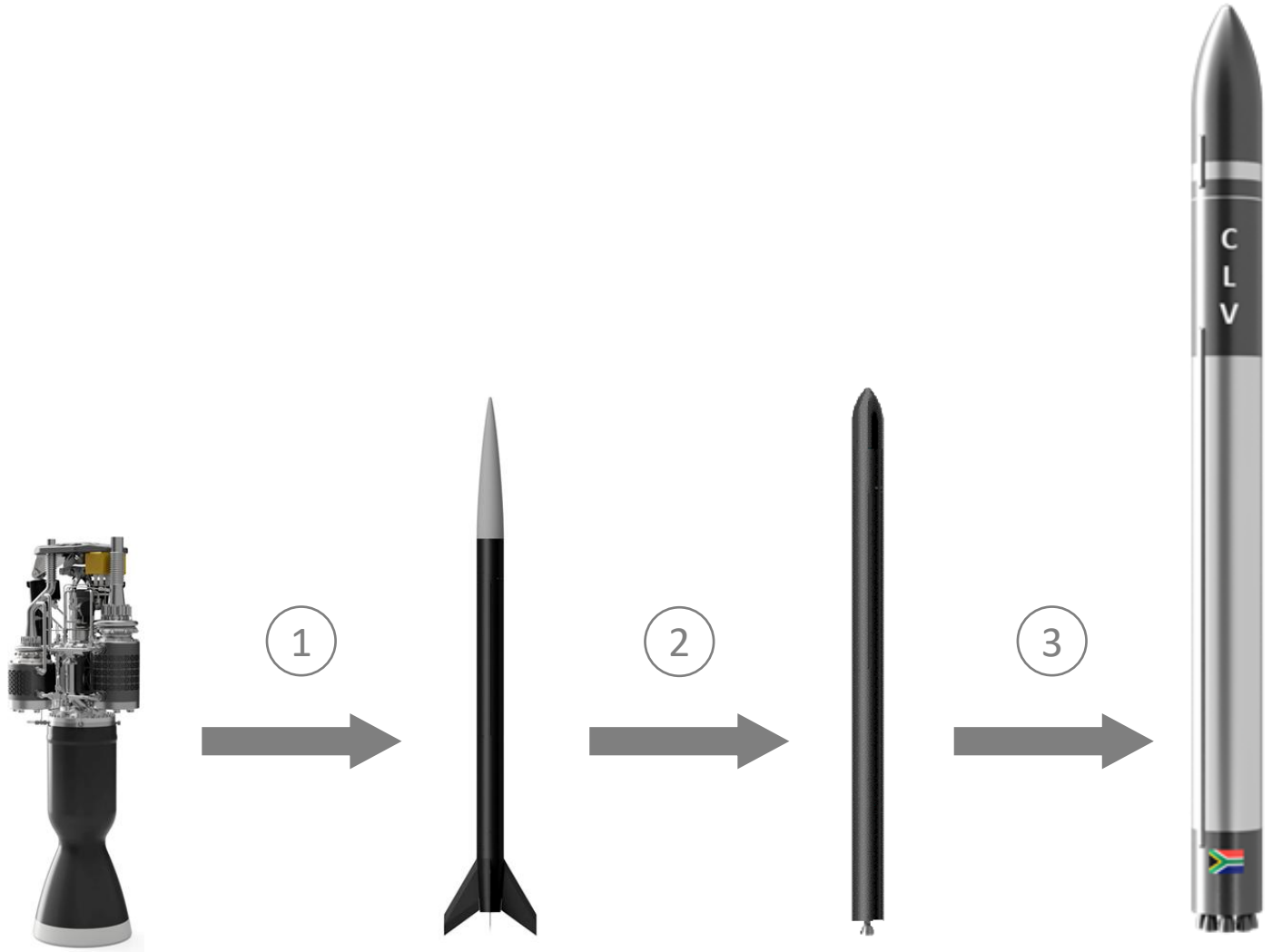
The SAFFIRE Liquid Rocket Engine

- Design philosophy: simplicity and cost-effectiveness over performance
- Thrust chamber: ablative cooling, filament-wound casing
- Propellant pumps: electrically-driven, powered by lithium batteries
- Specs:
  - Thrust: ≈27 kN (design point)
  - Combustion pressure: 35 bar
  - Propellant consumption: ≈10 kg/s



SAFFIRE Rocket Engine Testing

The Path to CLV



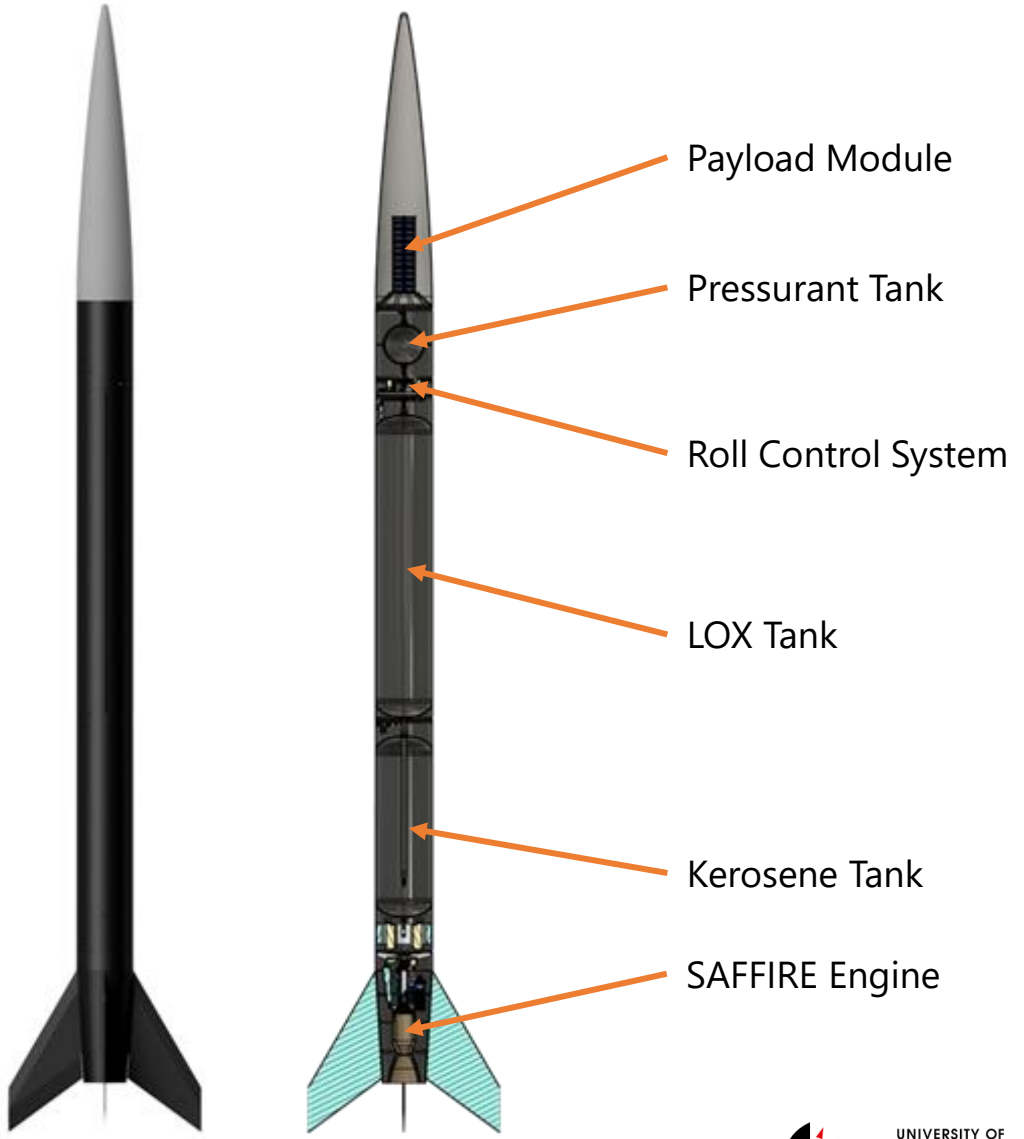
SAFFIRE Engine → STEVE → SmartSTEVE → CLV

The STEVE Sounding Rocket

- STEVE = Suborbital Test Vehicle
- Space-capable sounding rocket for flight-testing of SAFFIRE engine, CLV technologies/subsystems
- Aerodynamically-stabilised, unguided
- Height: ≈9 m, diameter: ≈0.5 m, lift-off mass: ≈1 tonne
- Targeting Q2 2027 for first flight test
- Will enable future suborbital space access for science, technology development and commercial missions

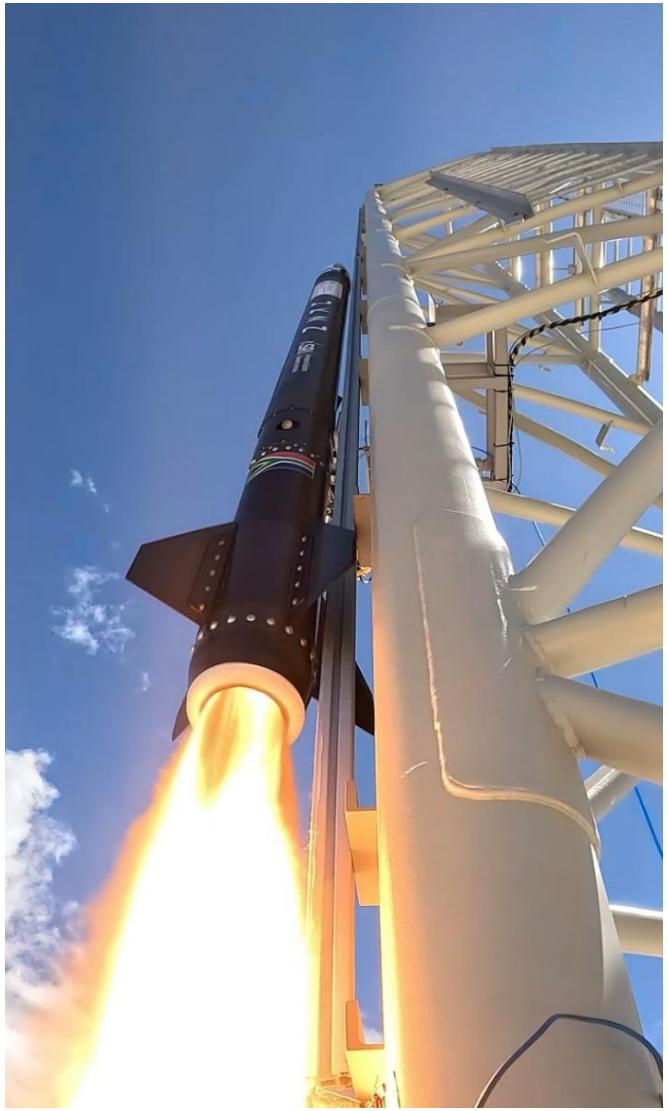
Propellant Tank Tube Mandrel

Propellant Tank Configuration



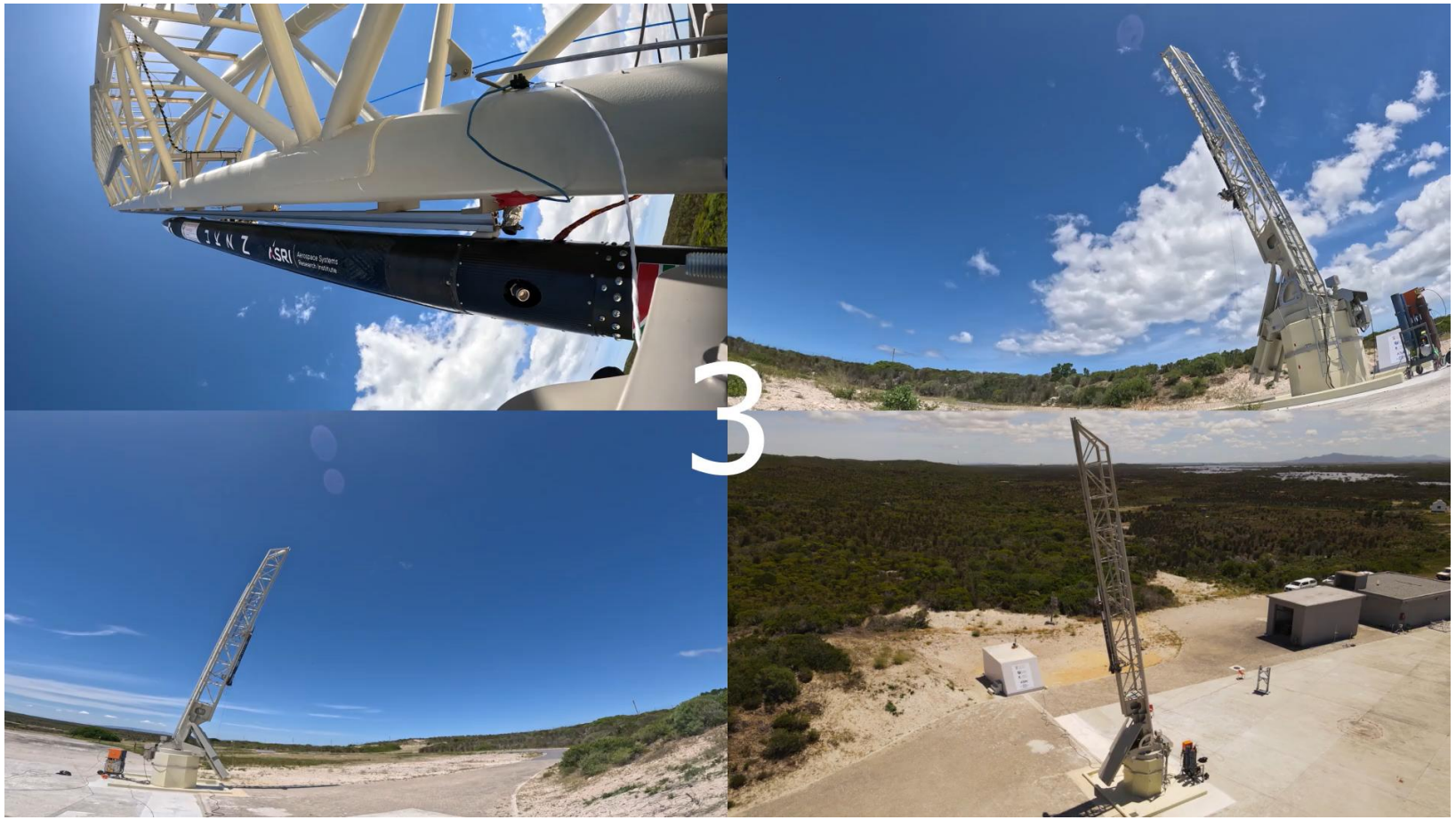
The Phoenix Sounding Rocket Programme

- Development of low-altitude sound rockets for:
  - Student training (equipment design, fabrication, testing; launch operations)
  - Technology testing (avionics, composite structures, payload systems)
  - STEM outreach
- Achievable altitude range: 10-20 km
- Propelled by hybrid rocket motors combusting liquid nitrous oxide and paraffin wax
- Pyrotechnic ignition system (sugar-potassium nitrate)
- Flight testing conducted at Denel OTR (8 missions between 2014 and 2024)
- Most recent flight test campaign: December 2024
- Next flight test campaign currently scheduled for Q2 2026



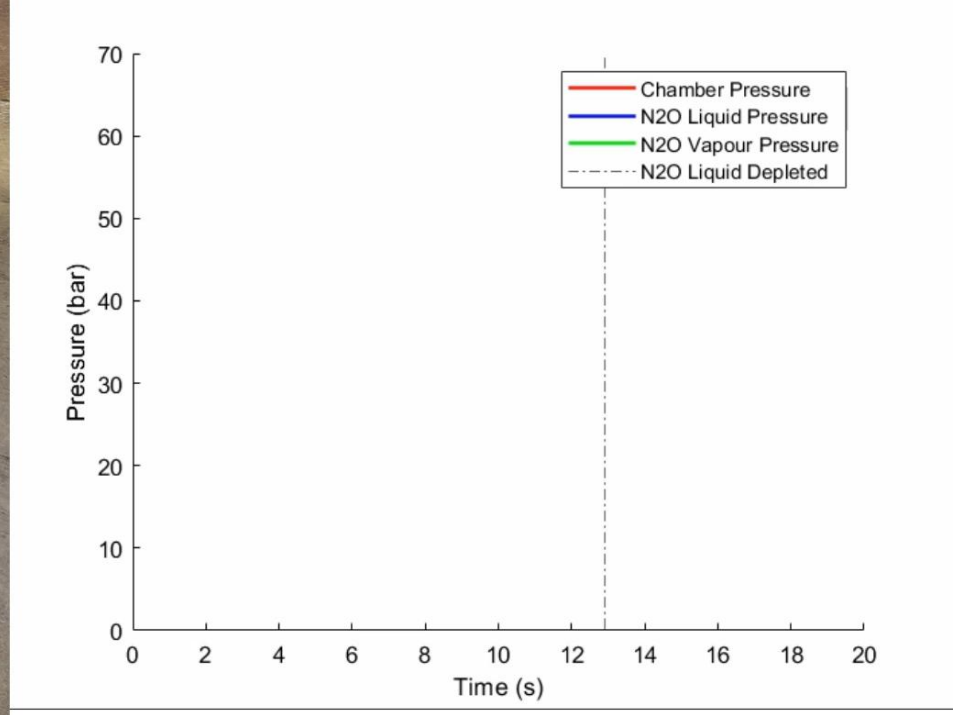
Phoenix Programme Testing

Phoenix-1D Flight Test (2024)



Phoenix Programme Testing

Phoenix Propulsion System Hot-Fire Test (2024)



In-Space Propulsion Programme

- Pursues the development of chemical thrusters for satellite and space tug propulsion
- Enabled by:
  - Dedicated laboratory for the formulation and testing of “green” gelled and liquid monopropellants
  - Small-scale propulsion test facility
- Focus on hydroxyl ammonium nitrate (HAN) based propellants
- 22 N thruster under development (battleship and flight-weight)
- In-house capabilities:
  - Propellant synthesis
  - Flow visualisation
  - Rheological characterization
  - Chemical vapour deposition (under development)

Green Propellants Laboratory

Battleship 22 N Thruster

Flight-Weight 22 N Thruster

ASRI's Facilities

South African Sounding Rocket Launch Facility

- Fundamental enabler of suborbital space access in South Africa
- Located at Denel OTR
- Commissioned in 2024
- Designed to launch Phoenix rockets, the STEVE rocket and an array of commercial sounding rockets
- Specs:
  - Vehicle mass capacity: 2 600 kg
  - Rail length: 15 m
  - Full-range remote azimuth and elevation control

ASRI's Facilities

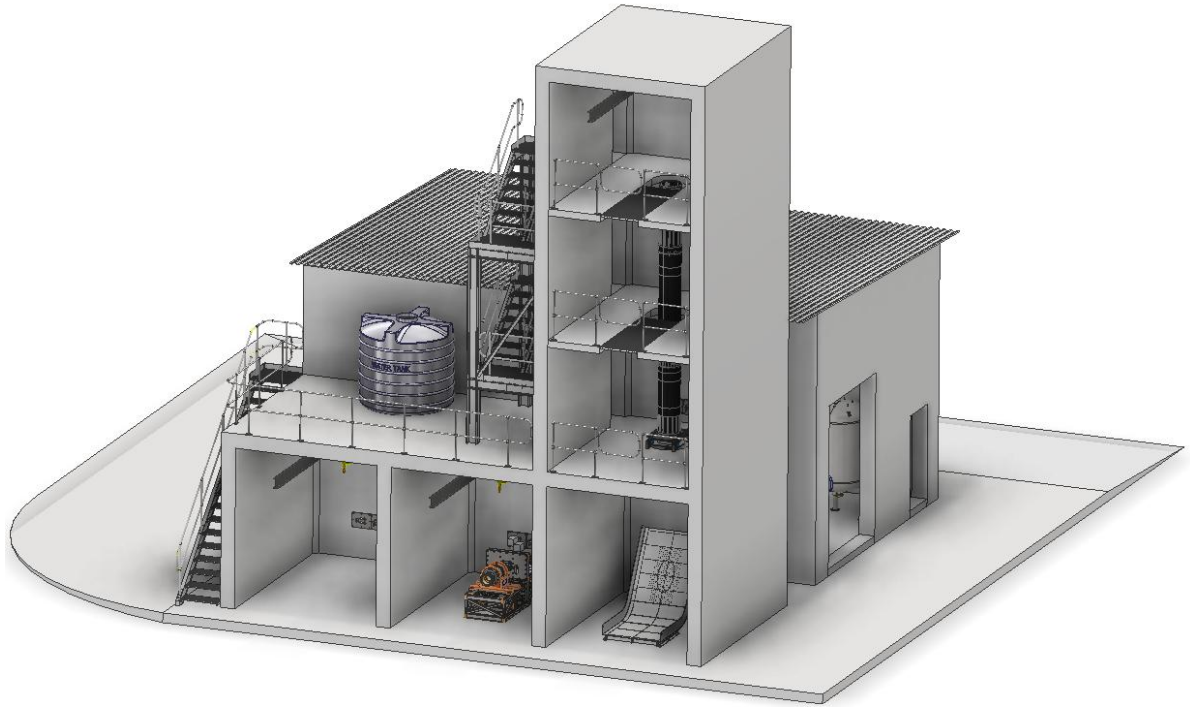
Advanced Manufacturing Facility

- Located within UKZN's Discipline of Mechanical Engineering building
- Supports in-house fabrication of ASRI rocket engine and launch vehicle components
- Offers commercial, aerospace-quality machining services
- Features:
  - World-class CNC machines (5-axis mill, 4-axis mill, mill-turn centre)
  - Coordinate measurement machine
  - Dedicated oxygen cleaning room
  - Control room for adjacent small propulsion test facility
  - Stores area for components, test rigs and materials
  - Engine and vehicle assembly areas

ASRI's Facilities

Propulsion Test Facility

- Designed to service ASRI's propulsion system development, qualification and acceptance testing requirements
- Two horizontal test cells, one vertical test cell
- To support:
  - SAFFFIRE engine hot-fire testing (up to 240 s)
  - STEVE sounding rocket hot-fire testing
  - CLV upper stage hot-fire testing
  - Phoenix hybrid rocket motor testing
  - Propellant injector and pump testing
  - Ignition system testing
- Location options: Denel OTR or UKZN
- Status: design complete (LochRoux), awaiting further approvals



ASRI's Facilities

Propulsion Test Facility

ASRI's Facilities

Additional Facilities

Mobile Propulsion Test Facility

Small Propulsion Test Facility

Propellant Pump Test Facility

ASRI and Explosives

- Although ASRI's technologies and facilities don't (yet) incorporate traditional explosives, certain oxidizer-fuel mixture scenarios are encountered that must be managed according to appropriate legislation:
  - Pyrotechnic igniters and initiators (sugar-potassium nitrate, epoxy-potassium nitrate, epoxy-potassium perchlorate)
  - Parachute recovery system mechanisms (black/smokeless powder)
  - Propellant mixtures within liquid rocket engine thrust chambers (liquid oxygen-kerosene)
- It is extremely rare for liquid oxygen-kerosene rocket engines to experience propellant detonation
- Nonetheless, for safety purposes, liquid oxygen-kerosene mixtures are typically regarded as having a TNT equivalency of 10 % by mass, as per NASA guidelines
- Looking to the (near) future: explosive charges for flight termination may well be required for launch vehicles from STEVE onwards

In Conclusion

- With the full backing of the DSTI and UKZN, ASRI is hard at work developing the technologies and human capital required for an indigenous space launch capability
- ASRI has grown into Africa's leading rocket propulsion and launch vehicle research entity
- To date, ASRI staff and students have dealt with liquid propellants and pyrotechnic igniters for over 15 years without a single associated injury (we fully intend to keep it that way!)
- Many exciting ground and flight tests lie ahead in the next two years
- We look forward to becoming part of the NIXT community!

Acknowledgements

We thank NIXT for inviting us to speak at this event, and gratefully acknowledge the support provided to ASRI by the following entities:

- The Department of Science, Technology and Innovation
- The University of KwaZulu-Natal
- The South African National Space Agency
- The National Research Foundation

Thank you for your time,
and feel free to contact us!

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