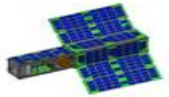


PROPSAT

Peter Merrick, Bryan Watson, Gerardo Pulido, Diego Gomes

Nomenclature

CubeSat – Pico satellite conforming to Cal-poly specifications

ALLSTAR – Agile Low-cost Laboratory for Space Technology Acceleration and Research

PROPSAT – Propulsion satellite

R-134a – 1,1,1,2-Tetrafluoroethane

Expansion Ratio – The ratio between throat area and the exit area

Delta V – Change in velocity

Mission Goal

- PROPSAT is a continuation and third revision of the ALLSTAR satellite system following polar cube.

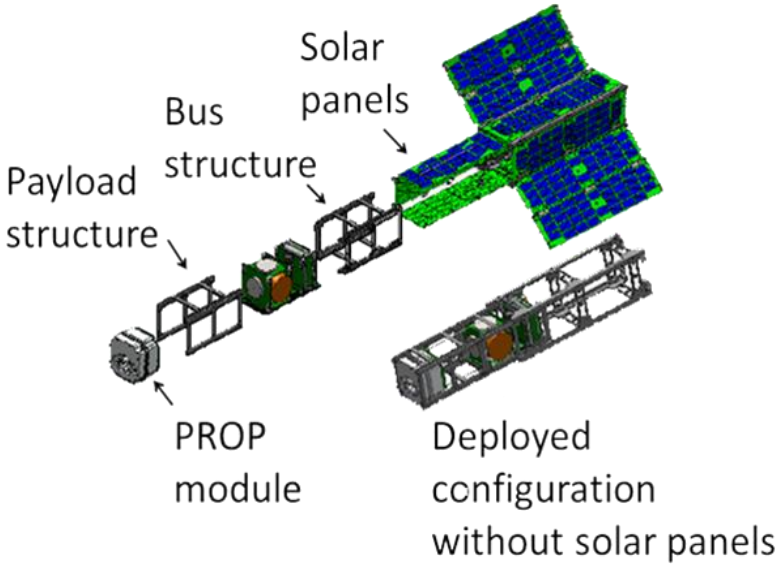
- The payload is designed to provide impulsive propulsion capability to ALLSTAR. Used for orbital maintenance and small impulsive maneuvers.

The PROPSAT Module

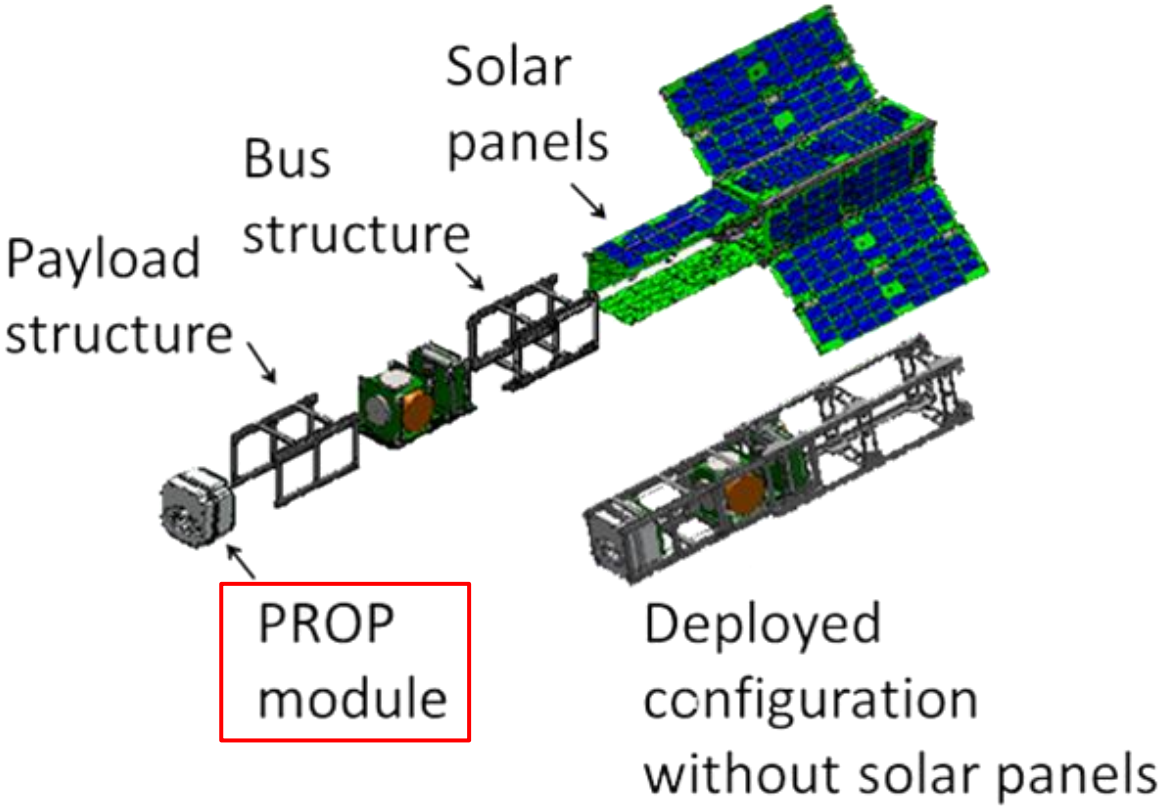
- The PROP module is cold gas thurster with R-134a as fuel.
- PropSat is a continuation of the ALLSTAR and PolarCube missions.
- It is a dedicated propulsion module for missions utilizing the ALLSTAR bus structure (3U CubeSat configuration)
- Part of NASA's CubeSat Launch Initiative

Integration with ALLSTAR

- Prop attaches to the edge of the payload section and takes up roughly ½ - unit of the payload section
- Prop will consume no more the 2 watts at any given time.
- Prop will be software controllable by the ALLSTAR avionics
- Allows 1-unit for science payload



ALLSTAR Bus Integration



Design Requirements

- Estimation for one year orbital maintenance
  - ALLSTAR requirement is 10 m/s impulsive
  - 1-Unit : 4.5 to 17 m/s
  - 3 unit : 3.5 to 20 m/s
    - Depending on orientation and solar state
- Attitude Estimation
  - 1-Unit : 1-3 m/s*
  - 3 unit : 2-4 m/s*
  - No ALLSTAR Requirement
- Power draw: 2 watts

Design Overview

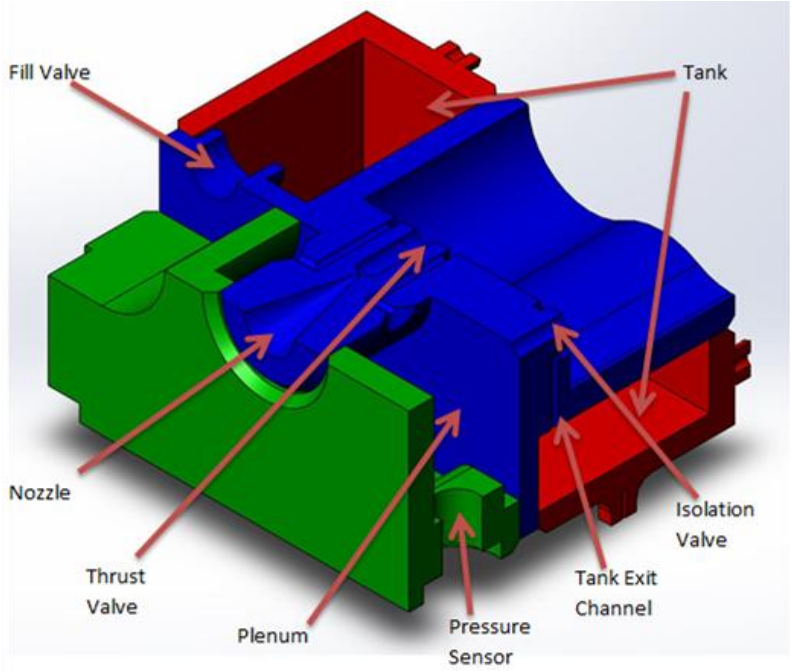
ALL-STAR

- Two-phase cold-gas propulsion system.
  - Phase one: saturated liquid
  - Phase two: gaseous state
- Uses R134-a propellant
  - High density
  - High molecular mass
  - Chemically inert
- Machined in four pieces out of 6061 Aluminum
- Pieces welded together using Electron beam welding

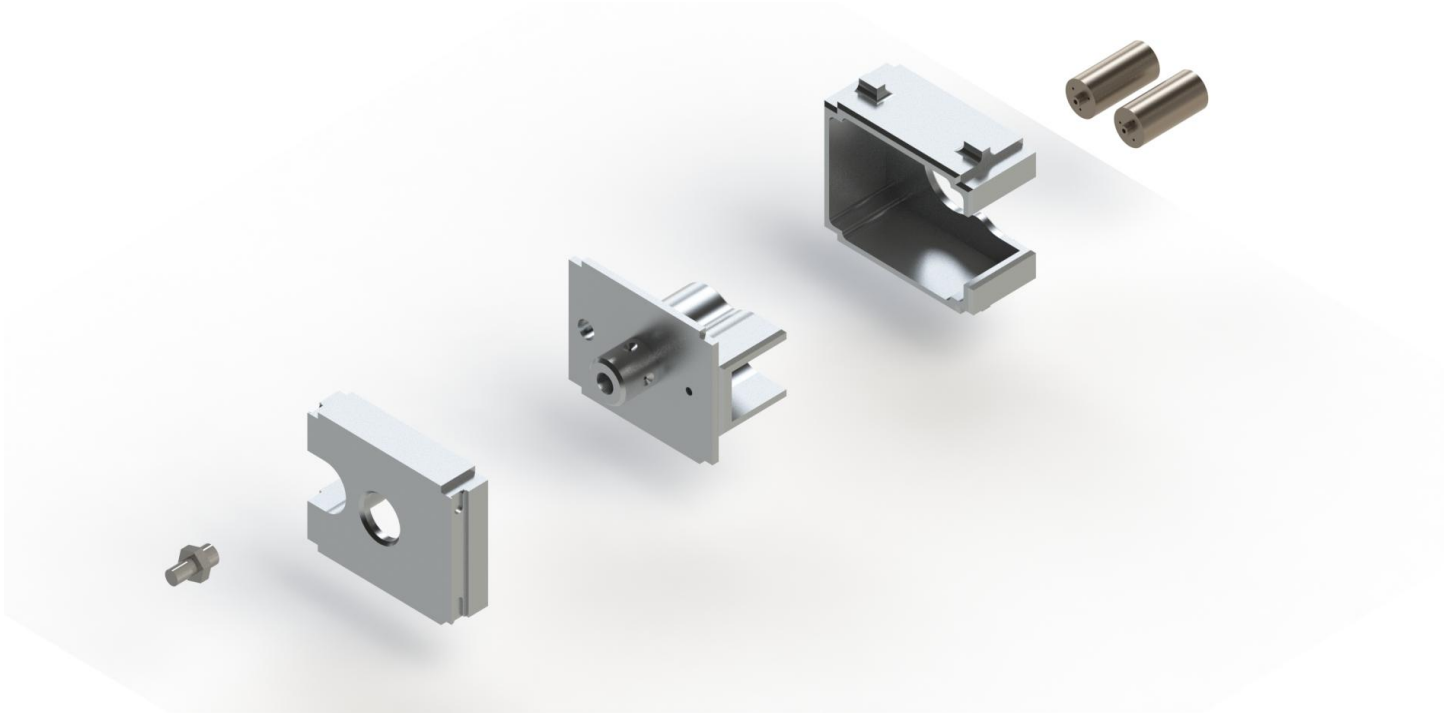
Design

ALL-STAR

- Tank
  - Stores saturated liquid R-134a
- Isolation valves
  - Transfers the fluid from the Tank to the Plenum
  - Plenum to exhaust
- Plenum
  - Stores pressurized R-134a vapor
  - Feeds from tank
- Nozzle
  - Speeds up the flow of the fluid
  - Expansion ratio of 460
  - Feeds from Plenum to exhaust



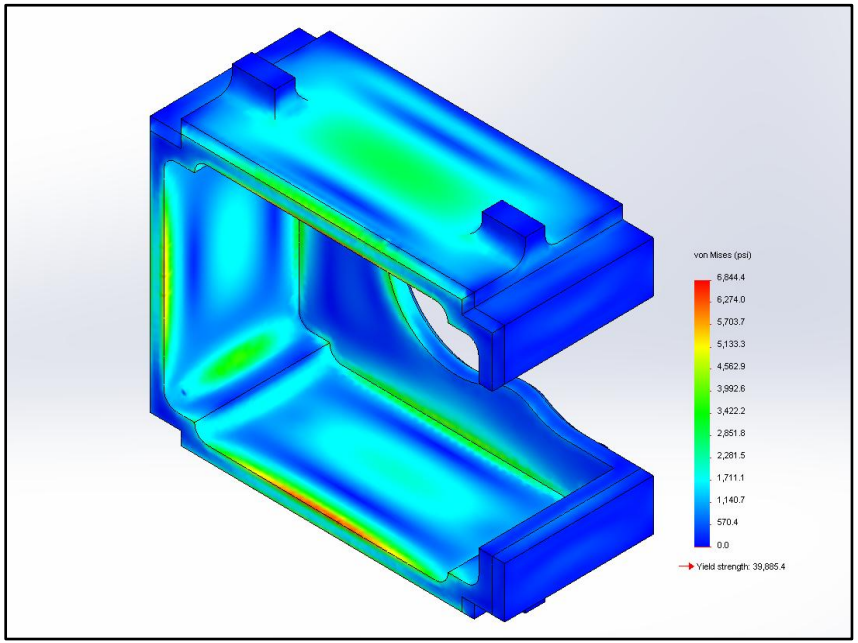
Exploded View



Tank Specifications

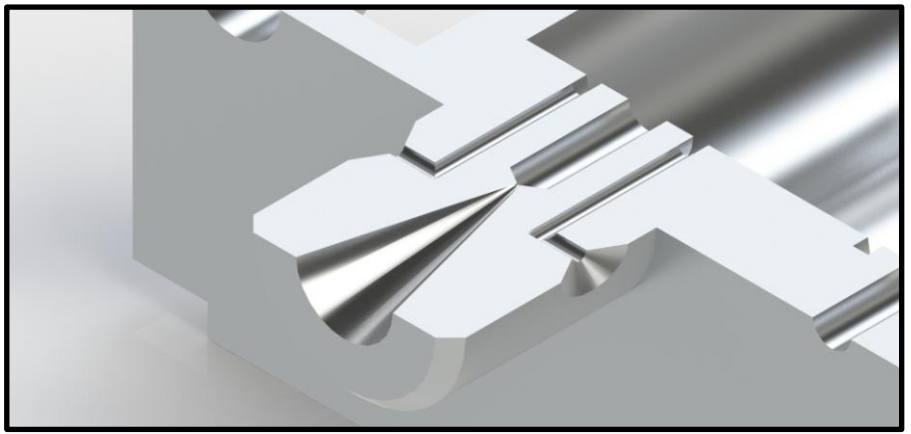
ALL-STAR

- Factor of safety of 4.38
- Tank volume of 6.43 cubic inches
- 6061 Aluminum
- Saturated Liquid
- 70 psi to 80 psi



Nozzle Specifications

- Expansion ratio 460
- Current ISP of 48-50 seconds
- Minimum Thrust of 4.983 X 10^-5 N
- Maximum operating pressure 200 psi



Propulsion

ALL-STAR

- Tank and plenum are heated by external patch heaters (limited to 2 watts total power draw)
  - Increased fluid pressure and overall efficiency
- Isolation valve opens and plenum is filled.
- Thrust valve opens allowing a quick, efficient burst of thrust.
- Control loop keeps plenum at optimal pressure via the isolation valve.

Performance

ALL-STAR

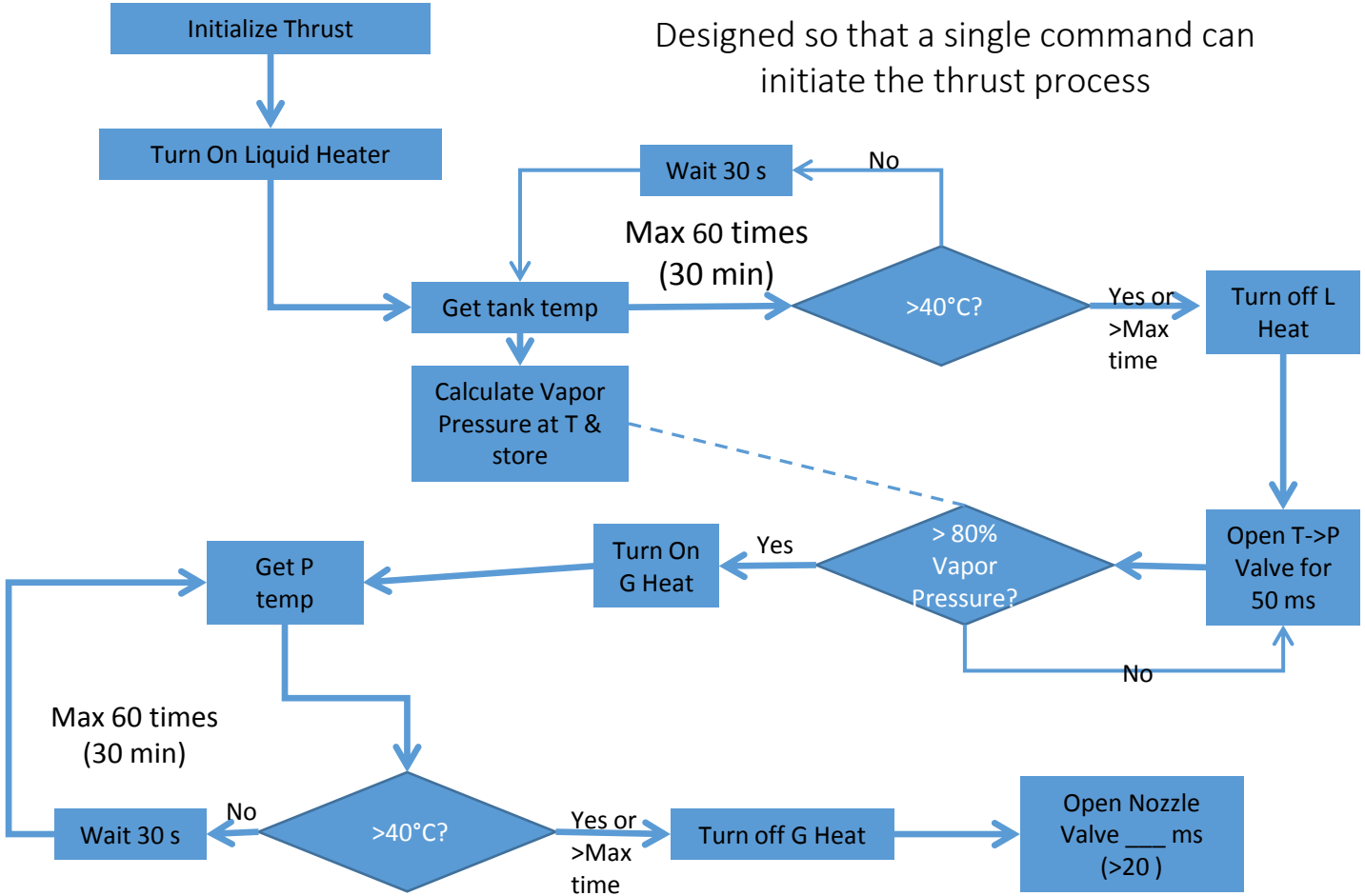
- Current design has a nozzle expansion ratio of 460
- Exit Mach number of 6.368
- Experimental ISP of 48-50 seconds
- Average estimated ΔV of 14.6m/s

Control

- PROPSAT thrust is dictated by ALLSTAR avionics and flight software
- PROPSAT is controlled by a control loop on a dedicated board secured to the outside of module
- Control loop uses stored thermodynamic data to estimate the states of propellant
- Board then controls valves and patch heaters based on estimates
- Helps keeps exit velocities more constant

Control algorithm

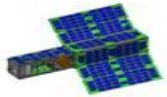
Designed so that a single command can initiate the thrust process



Lessons Learned

- Tasks take longer than expected
- Documentation is important
- Organization is helpful in the long run
- Unanticipated technical problems can always occur

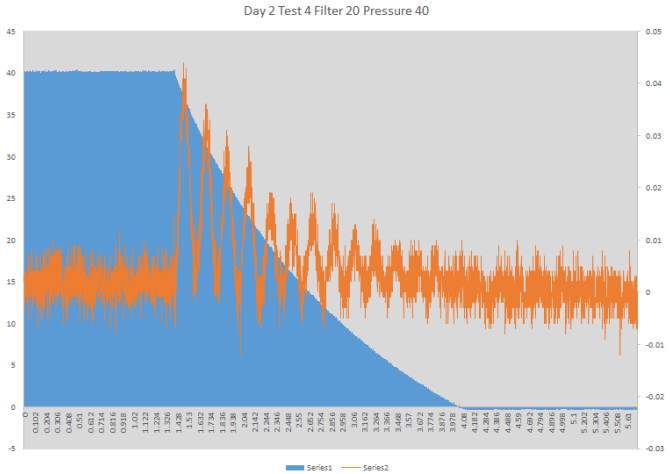
Benefits to the Scientific Community



- Small scale propulsion is something that has been tried a lot , but rarely done successfully. PROPSAT and the ALLSTAR bus hopes to provide and affordable and easily reproducible option for thrust on small scale satellites.
- This can provide a multitude of different possibilities

Future?

- More environmental and performance testing to be completed
- PolarCube completion
- Launch opportunities:
  - CubeSat Initiative Launch Secured
  - CubeQuest Centennial Challenge



Conclusion

ALL-STAR

- PROPSAT is used for orbit sustainability and small impulsive manuevers
- PROPSAT is a usable, scalable propulsion method that could be utilized on a wide variety of platforms.

Acknowledgements and Thank you's

- Chris Koehler – Colorado Space Grant Consortium
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- The PROPSAT Team – Current and former members
- ALLSTAR Team
- PolarCube Team

References

- Kennewell,J.,Panwar,R.,”Satellite Orbital Decay Calculations,” IPS Radio and Space Services,Sydney,Australia,1999
- Pender,A.,”CubeSat Propulsion Subsystem Design,” Jan. 2013