NC STATE UNIVERSITY

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ARISE

Spacepack Balloonatics

Aerospace Engineering Capstone Senior Design 2023 – 2024
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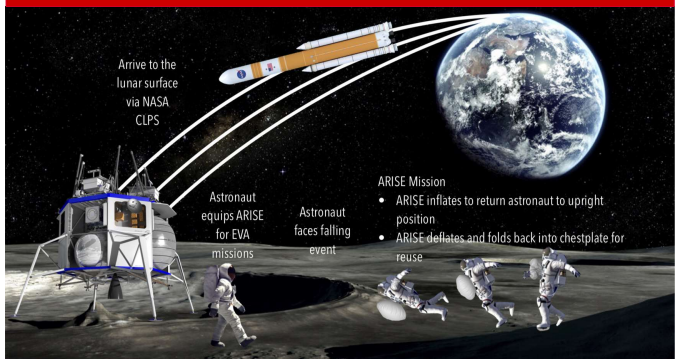
Project Overview

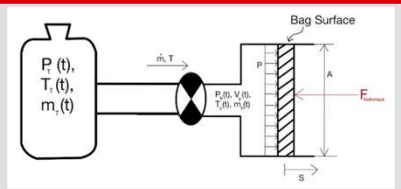
ARISE (**A**stronaut **R**ecovery **I**nflatable **S**upport **E**quipment) is an astronaut mobility support system that assists posture recovery after a falling event during extravehicular activities (EVAs) on the lunar surface:

Obj 1: Evaluate ARISE design solution to establish evidence of feasibility.
Obj 2: Manufacture ARISE prototype to design specifications.
Obj 3: Conduct validation and verification testing (TRL 4) on ARISE systems.

ConOps



Theory



Bag Thermodynamics

1st Law of Thermodynamics:

$$\frac{dm_b}{dt}e + m_b c_v \frac{dT_b}{dt} = \frac{dm_b}{dt}\left(h + \frac{v^2}{2}\right) - P_b\frac{dV_b}{dt}$$

Ideal gas law:

$$\frac{dP_b}{dt} = \frac{dm_b}{dt}\left(\frac{P_b}{m_b}\right) + \frac{dT_b}{dt}\left(\frac{P_b}{T_b}\right) - \frac{dV_b}{dt}\left(\frac{P_b}{V_b}\right)$$

Mass continuity:

$$\frac{dm_b}{dt} = const$$

Volume change:

$$\frac{dV_b}{dt} = A\frac{ds}{dt}$$

Bag linear expansion rate:

$$\frac{ds}{dt} = \left[(h-b)cos(\theta)\frac{d\theta}{dt} + \frac{dy}{dt} + (s)sin(\theta)\frac{d\theta}{dt}\right]sec(\theta)$$

Bag expansion length:

$$s = [(h-b)sin(\theta) + y]sec(\theta)$$

Tank Thermodynamics

1st Law of Thermodynamics:

$$\frac{dm_t}{dt}e + m_t c_v \frac{dT_t}{dt} = \frac{dm_t}{dt}\left(h + \frac{v^2}{2}\right)$$

Redlich Kwong Equation of State

$$\frac{dP_t}{dt} = \left[\frac{R_u}{(V_m - b)} + \frac{a}{2V_m(V_m+b)T_t^{3/2}}\right]\frac{dT_t}{dt} - \dots$$

$$\dots - \frac{V_m}{m}\left[\frac{ab}{V_m^2(V_m+b)^2\sqrt{T_t}} + \frac{2a}{V_m(V_m+b)^2\sqrt{T_t}} + \frac{R_u T_t}{(V_m-b)^2}\right]\frac{dm_t}{dt}$$

Molecular attraction correction:

$$a = 0.42748\frac{R_u^2 T_c^{2.5}}{P_c}$$

Volume correction:

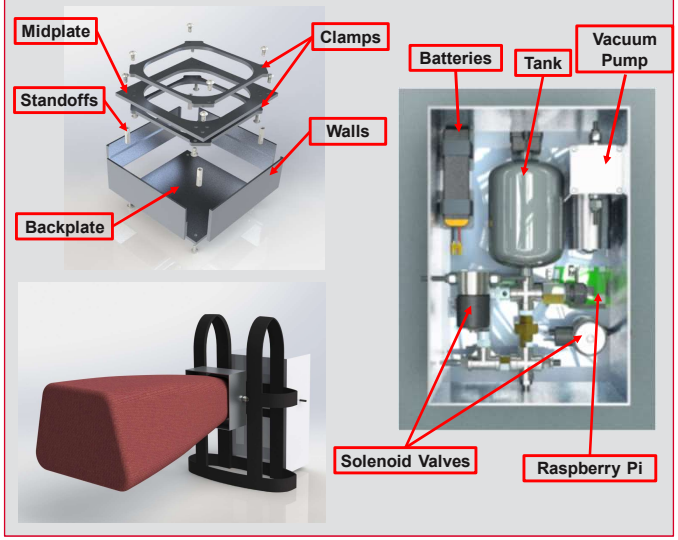
$$b = 0.08664\frac{RT_c}{P_c}$$

Mass continuity:

$$\frac{dm_t}{dt} = -\frac{dm_b}{dt}$$

Design Solution

The design solution of ARISE is a modular and effective solution to astronaut fall events. Through a series of trade studies, numerical calculations, and simulations, the design for ARISE was done with considerations of weight, manufacturability, cost, and effectiveness. The design of individual components of ARISE was handled by each sub-team lead to optimize performance and improve prototyping time. The final design of ARISE is highlighted below:



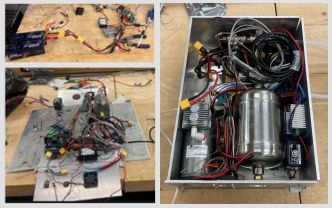
Manufacturing

Front Housing:

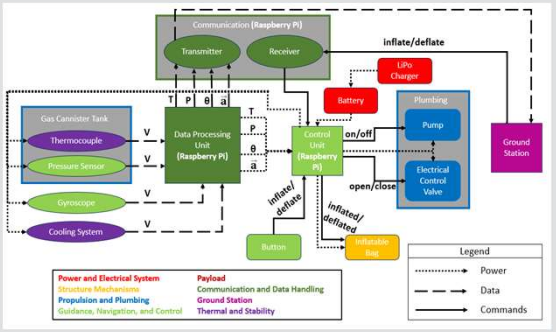
- Bag: Sew nylon ripstop material
- Bladder: Heat seal, sew seams, flex seal
- Clamps and Midplate: Waterjet, aluminum 6061 alloy
- Side Walls: Machine and weld aluminum sheets

Back Housing:

- Welding aluminum
- Milling holes for tubing and electronics
- Layup of components
- Soldering of power circuit
- Plumbing assembly



Functional Block Diagram



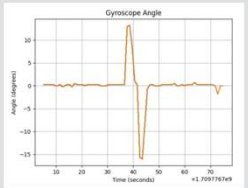
Final Prototype

Testing

Inflation Test:

Front housing pack flipped over and full inflation/deflation cycle was tested to determine if housing pack "pops" off the ground.

Ground Station Test:



Putting the electronics and communications systems to the test, the angle of ARISE is live-plotted on a computer via Raspberry Pi and gyroscope.

Power Test:

Checking the voltage of the batteries after each inflation and deflation, power tests were done to ensure mission longevity.