Pressure Suit Design Considerations for Extreme High-Altitude Bailout – Lessons Learned from Red Bull Stratos

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Disclosure Information

Shane E. Jacobs

I have the following financial relationships to disclose:
• Employee of: David Clark Company Incorporated

I will not discuss off-label use and/or investigational use in my presentation.
Introduction

• From a suit design perspective, this project was a unique opportunity to prove out and validate equipment, and to collect data.

• Use of a pressurized capsule, the team of subject matter experts, and potential for science were some of the key discriminators.

• Opportunity to develop procedures and techniques required to recover crews from high altitudes.
Suit Design Requirements

• Used current state-of-the-art as basis for design
  – Baseline is designed for cockpit and ejection seat, therefore redesign needed

• Suit addressed unique requirements
  – Skydiving pose (Delta Position)
  – Standing on step – transitioning from seated to standing
  – Thermal considerations
Historically, pressure suits are bulky, heavy, and made of impermeable materials that trap heat and water vapor.

The suit used as the baseline for this design employs breathable and lightweight materials, making it low-bulk, lightweight, comfortable and low thermal burden.
Baseline Pressure Suit

- Breathable (airtight) gas container to reduce thermal burden
- Integrated vent assembly for cooling
- Link-net restraint provides unpressurized comfort and pressurized mobility (within the design range)
- Exterior cover provides fire protection as well as protection from abrasion, puncture, etc.
Baseline Helmet

- Integrated oxygen delivery system provides required oxygen, ensures CO2 washout, and aids mitigation of visor fogging, while minimizing consumable usage
- Phase Change Materials in helmet liner help maintain thermal comfort
- Composite shell, along with attenuation liner, provide impact protection while minimizing head-borne mass
- Integrated visor-fogging mitigation system
Unique Design Specifications

- Patterning of shoulder, elbow, hip and knee to obtain Delta position
- Hold-down design allows for transition from seated to standing position
Suit Development

- Custom fit to Felix’s Anthropometry
- Three suits were fabricated for use in the testing and development program
- Each suit was subjected to a series of acceptance tests prior to use including leak tests, structural tests, and fit checks
  - S01 – Prototype/Training Suit
  - S02 and S03 – Operational Suits
Fit Checks
## S02 Data

<table>
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<tr>
<th>Assembly</th>
<th>Date of Manufacture</th>
<th>Pre-Delivery Leak Rate (sccm)</th>
<th>Leak Rate Post End of Program (sccm)</th>
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<tbody>
<tr>
<td>Helmet</td>
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<tr>
<td>Coverall</td>
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</table>

- This operational suit used for some vacuum chamber testing, MBF1 and MBF3
- Post-flight inspection shows suit is in pristine condition with all systems working as designed
- No delamination of gas container nor any other anomalies noted
- Leak rate remains negligible - maximum allowable leak rate is 1600 sccm for coverall, 4400 for whole system
Suit Integration

- Additional Modifications to Suit/Helmet
  - GPS and Antennas integrated
  - Modification to visor and sunshade to use sunshade as additional thermal pane
  - Boot heaters integrated
  - Camera pockets
  - Glove mirrors
Chest Pack Integration

• Chest pack includes:
  – 3 GPS Units
  – Video Camera
  – Radio
  – Sensors (accelerometer, IMUs, etc.)
  – Lithium ion batteries for comm and visor heating

• Chest pack swings away for landing
Parachute and Oxygen System

• Custom parachute system integrated with suit, includes:
  – Drogue, Main and Reserve chutes
  – Custom handles, with placement considerations based on suit integration
  – Drogue deployment device (“G Whiz”)
  – Automatic activation device on reserve (CYPRES)

• Redundant oxygen bottles
  – 5.5 cubic feet (155 L) each
  – 2500 psi (17.2 MPa)
  – Provide ~14 minutes of gaseous oxygen, once disconnected from vehicle supply
Fully Integrated Suit
Operational Testing

• This was a flight test program
  – Cold Chamber Tests
  – Vertical wind tunnel tests
  – Unpressurized skydiving
  – Pressurized skydiving
  – Thermal vacuum chamber testing
  – Bungee Jumping for step-off testing
Skydiving Training
Step-off Testing
Discussion

• All suit systems performed as designed and no anomalies were noted during post-flight inspections
• This project expanded the performance envelope for David Clark pressure suits and associate aerospace crew protective equipment
• Red Bull Stratos provided validation of the pressure suit design and procedures related to crew survivability and bailout from extreme altitude
• Lessons learned will be applied to future suit designs for commercial spaceflight and future government vehicles
The authors acknowledge the invaluable contribution to the spaceflight scientific community that Felix Baumgartner and Red Bull are making by releasing the data obtained throughout the Red Bull Stratos Project.

The authors also acknowledge the invaluable support of the following:

– Red Bull N.A.
– The Red Bull Stratos team
– Col Joe Kittinger, USAF (ret)
– Art Thompson and the Sage Cheshire Aerospace Team
Questions?
Backup Slides
This prototype suit used for multiple operational tests
Exterior cover shows some signs of wear, but overall suit is still in excellent condition
No damage or wear evident in gas container or restraint
Leak rate remains negligible - maximum allowable leak rate is 1600 sccm for coverall, 4400 for whole system
### S03 Data

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Date of Manufacture</th>
<th>Pre-Delivery Leak Rate (sccm)</th>
<th>Leak Rate Post End of Program (sccm)</th>
</tr>
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<tbody>
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<td>Helmet</td>
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</table>

- This operational suit used for MBF2
- Post-flight inspection shows suit is in pristine condition with all systems working as designed
- No damage or wear evident in gas container or restraint
Visor Heat Configuration

- S1034E helmet connector plugs into “Y” connector, one connector to aircraft, one to ejection seat
- In nominal operation, power is provided by the aircraft
- Pilot can select appropriate level of heating as required (off, 1-7)
- In the case of an ejection, power for visor heat automatically switches to a battery in the ejection seat
- The ejection sequence activates the battery and switches power
- At ~15,000 feet, the man-seat separator activates, separating the pilot from the seat
- At that point, face heat is no longer needed nor provided
Heating Element
Stratos Configuration

• Helmet connected directly to capsule or chest pack
  – During troubleshooting, Felix disconnected from vehicle and connected directly to chest pack
  – Chest pack had single, “high” setting
  – This demonstrated that visor heating was working as designed