Overview of Physiological and Medical Risks and Mitigation

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I have the following financial relationships to disclose:

Consultant for: Sage Cheshire Aerospace Corporation
Consultant for: Red Bull N.A.

I will discuss the following off-label use and/or investigational use in my presentation:

- High-Flow Percussive Ventilation for ebullism-related pulmonary injury
- Hidalgo Equivital™ for non-invasive hemodynamic monitoring for spaceflight applications
Historic Lessons Learned

- USAF Project Excelsior Jumps – 120 rpm flat spin (Excelsior-1), glove leak (Excelsior -3)
- USN StratoLab V balloon flight – drowning fatality
- Russian Air Force Volga Balloon Jump – cracked visor, ebullism fatality
- Project Strato Jump (US Civilian) – visor opened, anoxia, delayed fatality
- SR-71/ A-12 Aircraft - Mach 3+ 78K breakup, 3 of 4 crew survive breakup, 1 fatal neck injury, 1 drowning fatality
Excelsior I jump
Joe Kittinger goes into 120 rpm flat spin and goes unconscious
Excelsior III Jump
Joe Kittinger shows right hand swelling following glove leak
Project StratoLab V

NAVY BALLOONISTS

Lt. Cdr. Victor G. Prather, left, and Cdr. Malcolm Ross, who are shown during a press conference in Pensacola, Fla., early this week, were aboard the huge balloon which soared 21 1/2 miles above the Gulf Thursday.

21 1/2-MILE ASCENT

PENSACOLA, Fla. (UPI) — Two “sub astronauts” soared a record 21 1/2 miles into the stratosphere Thursday but one of the men was killed during pick-up operations in the Gulf of Mexico.

The Navy said that Lt. Cdr. Victor G. Prather, a surgeon who made the flight as an observer, was fatally injured when he fell from the gondola of a helium-filled balloon which puffed the balloonists from the water.

Prather died in the sick bay of the aircraft carrier Antietam a short time later, Cdr. Malcolm Ross, the pilot of the giant plastic balloon, was not injured, the Navy said.

The 411-foot-high balloon, dubbed “Stratolab High No. 5,” was launched from the Antietam Thursday morning and rose to an altitude of 133,500 feet, a record height for manned lighter-than-air flight. Ross and Prather were clad in pressurized suits.

The purpose of the launch, sponsored by the Office of Naval Research, was to study the effects of high altitude on the human body and to test the pressure suits in temperatures as low as 65 degrees below zero.

Ross and Prather were in a gondola hanging from the giant balloon, filled with helium. The balloon descended perfectly and landed in the Gulf near the Antietam. A helicopter flew over the floating gondola and lowered a sling seat. Ross was brought safely aboard the helicopter but Prather fell into the water as the sling was being raised to the cutter.

Lt. (j.g.) Kenneth Benson, a member of the rescue team, dived into the Gulf and retrieved Prather, still clad in his helmet and pressurized suit. Benson put the unconscious officer aboard a motor boat which took him to the Antietam. Prather died one hour and 30 minutes later without regaining consciousness.

The tragedy marred a record-breaking flight which had been postponed three times by adverse weather conditions.
Russian Volga Stratospheric Parachute Test Program
Unconscious Piantanida Treated In Minneapolis

MINNEAPOLIS (AP) — Parachutist Nick Piantanida, deprived of oxygen for three critical minutes in a futile try at a record parachute fall Sunday, fought for his life—and for recovery from undetermined brain damage—in a Minneapolis hospital Monday.

The 33-year-old Brick Town, N.J. man, whose balloon plunged to the ground in southwestern Minnesota Sunday from an elevation of 57,000 feet, was placed in a hyperbaric chamber at Hennepin County General Hospital shortly after 7 a.m. today.

The chamber permits intensive oxygen treatment of the body, and other related care.

Dr. Claude Hitchcock, chief surgeon of the hospital, said the vital question of degree of brain damage could not be answered yet.

Dr. Leonard Thomson, flight surgeon on Piantanida's last two flights, said the chutist appeared to have suffered no physical damage other than to his brain from his dangerous plunge.

Thompson estimated it had taken Piantanida three minutes to descend from 57,000 feet.
SR-71 Blackbird Breakup at Mach 3.18 / 78,000 ft (1/25/1966)
Lessons Learned from Stratospheric Aircraft / Balloon Flights and Vacuum Chamber Events

- Contact between vehicle and crew during egress can breach the pressure suit integrity

- A flat spin in free fall can render a jumper unable to perform physical activities or render them unconscious or can be fatal

- Localized suit leak may result in focal tissue swelling from ebullism

- An inflated suit can act to limit functional mobility and limit injury potential during supersonic / transonic transitions
Lessons Learned from Stratospheric Aircraft and Balloon Flights and Vacuum Chamber Events

• Exposure to near vacuum for seconds is survivable with no medical care

• Exposure to near vacuum for a minute is survivable with aggressive medical care

• Exposure to altitudes below Armstrong’s Line (63,000 feet / 19,202 m) for many minutes has been initially survivable but with severe neurologic dysfunction (coma)

• The post-landing environment is still a threat to survival
Red Bull Stratos
Technical Objectives

• Demonstrate advanced features of next generation pressure suit

• Expand envelope for crew escape

• Determine if stratospheric freefall without use of stabilization parachute is possible

• Determine if penetration of transonic region in freefall is possible
Red Bull Stratos Milestones

2005
- Felix and Red Bull request groundwork for project to begin with Sage Cheshire Aerospace Corporation

2006
- Sage Cheshire begins Planning and team recruitment, capsule and system development begins
- Col. Kittinger joins team
- David Clark Co. agrees to sell and produce suits to Sage Cheshire for the Red Bull Stratos program

2007
- Personal parachute system development begins
- Capsule Construction begins
- High-altitude balloons secured
- Felix conducts first high-altitude training in pressure suit at Beale AFB

2008
- Wind tunnel testing and training in pressure suit
- Capsule and suit thermal vacuum test at Brooks Chamber

2009
- 2nd Chamber test at Brooks
- Capsule man-rated to 121,000’
- Unmanned balloon flight #1

2010
- Unmanned balloon flight #2
- Manned balloon flight #1

2011
- Manned balloon flight #2
- 3rd Chamber test at Brooks
- Manned balloon flight #3
Red Bull Stratos Test Program

• Low pressure chamber tests
  – pressure suit and life support system

• Vertical wind tunnel and free fall tests
  – personal parachute system and pressure suit

• Suspended platform bungee step-off tests

• Free fall flight tests (high troposphere)
  – pressure suit and life support systems

• Integrated thermal/vacuum chamber tests
  – capsule, spacesuit, parachute, life support systems
  – 100K ft (30,480 m), -60°F (-51°C)
Red Bull Stratos
Test Program

Images courtesy of Red Bull Stratos
Red Bull Stratos
Medical Objectives

• Identify the technical challenges of individual crew escape systems

• Recognize the feasibility of survival from a supersonic atmospheric re-entry

• Demonstrate how medical treatment protocols for cabin pressure loss may apply to human spaceflight
Primary Threats for Stratospheric Bailout

1) Low altitude abort (<4,000 ft / 1,219 m balloon failure)
   - Hard landing with occupant in capsule

2) Low pressure / vacuum exposure
   - Hypoxia
   - Decompression Sickness
   - Ebullism

3) Acceleration Forces
   - Flat Spin (Negative Gz)
   - Shock Wave Forces

4) Landing Injury
   - Trauma
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<tr>
<th>Name</th>
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<tbody>
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<td>Jonathan Clark MD, MPH</td>
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<td>Sean Norton</td>
<td>Technical Rescue Paramedic</td>
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Red Bull Stratos Educational Projects

• Ebullism Treatment Protocol Development
• Emergency Medical Response Planning
• Negative Gz Prevention and Treatment Protocol Development
• Crew Recovery Protocol Development
• Accelerometers and Physiological Monitoring System Development
Red Bull Stratos
Medical Technical Consultants

- Andy Walshe Ph.D.  Red Bull High Performance Director
- Michael Gervais Ph.D.  Sports Psychologist
- Andy Pilmanis Ph.D.  Aerospace Physiologist
- Gresham Bayne M.D.  Critical Care Consultant
- Jim Bagian M.D.  Safety/ Survivability Consultant
- Robert Dunn M.D.  Hyperbaric Medicine Consultant
- Jim Sheffield M.D.  Hyperbaric Medicine Consultant
- Chris Stokely Ph.D.  Aerodynamics Reentry Expert
- Jeff Chancellor  Space Weather Radiation Physicist
Red Bull Stratos
Medical And Physiologic Support

- Medical/physiologic threat brief
- Low pressure, low temperature, acceleration risks
- Oxygen prebreathe protocol for Decompression Sickness risk reduction
- Medical/physiological monitoring plan
- Launch and recovery medical plan
- Contingency plan
- Medical protocol development against known threats during a stratospheric bailout
  - Ebullism treatment protocol for exposure to vacuum from a suit depressurization
  - Medical protocol for flat spin with negative Gz acceleration
Physiological Monitoring System
Panel Learning Objectives

- Describe the medical concerns and contingencies faced during Red Bull Stratos
- Discuss the medical protocols developed to mitigate the risks
- Discuss the biomedical results of the Red Bull Stratos Project
The medical team acknowledges the invaluable contribution to the spaceflight scientific community that Felix Baumgartner is making by releasing his data obtained throughout the Red Bull Stratos Project.

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