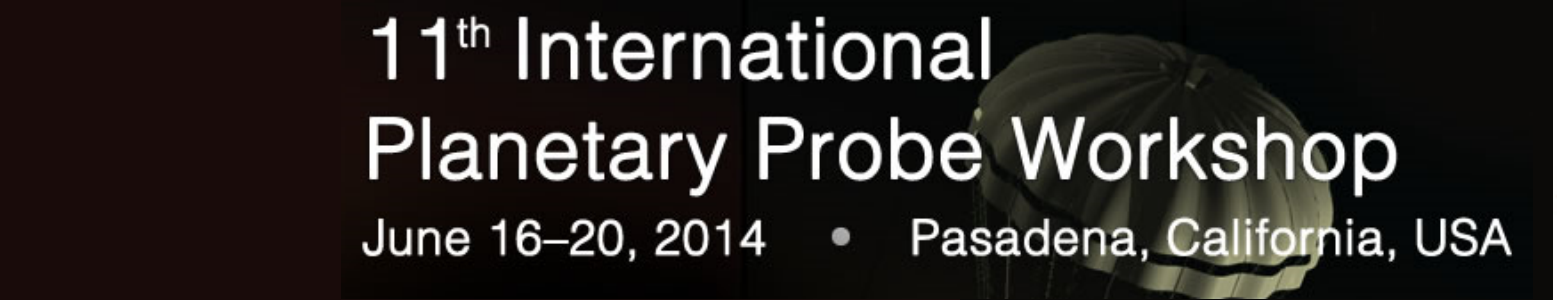

Development and Testing of a Titan Super Pressure Balloon Prototype

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Pasadena, CA

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Government sponsorship acknowledged.

Why use Super Pressure Balloons at Titan?

- **Conduct atmospheric science and explore surface features for weeks while covering a significant area of Titan**
- **Super Pressure Balloons have been used in ultra-long duration balloon science programs on earth**
- **Pressurized under all float conditions - provides stability at float altitude**
- **No heat source such as MMRTG is required to maintain buoyancy**
- **At cryogenic temperatures, helium diffusion through balloon membrane is essentially zero**
- **Public engagement using a fascinating science platform**

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Development and Testing Objectives

- **A future Titan mission using a balloon science platform could possibly operate for several months - exploring a significant portion of the atmosphere and surface.**
- **Nobody, to our knowledge, has performed cryogenic experiments on a balloon system to demonstrate near zero helium leakage from diffusion through the balloon film.**
- **We designed a balloon system test demonstrating that at Titan-like temperatures, the helium loss through the balloon film is so low that it can remain in a super pressure state for several months.**

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"Titan emerges"
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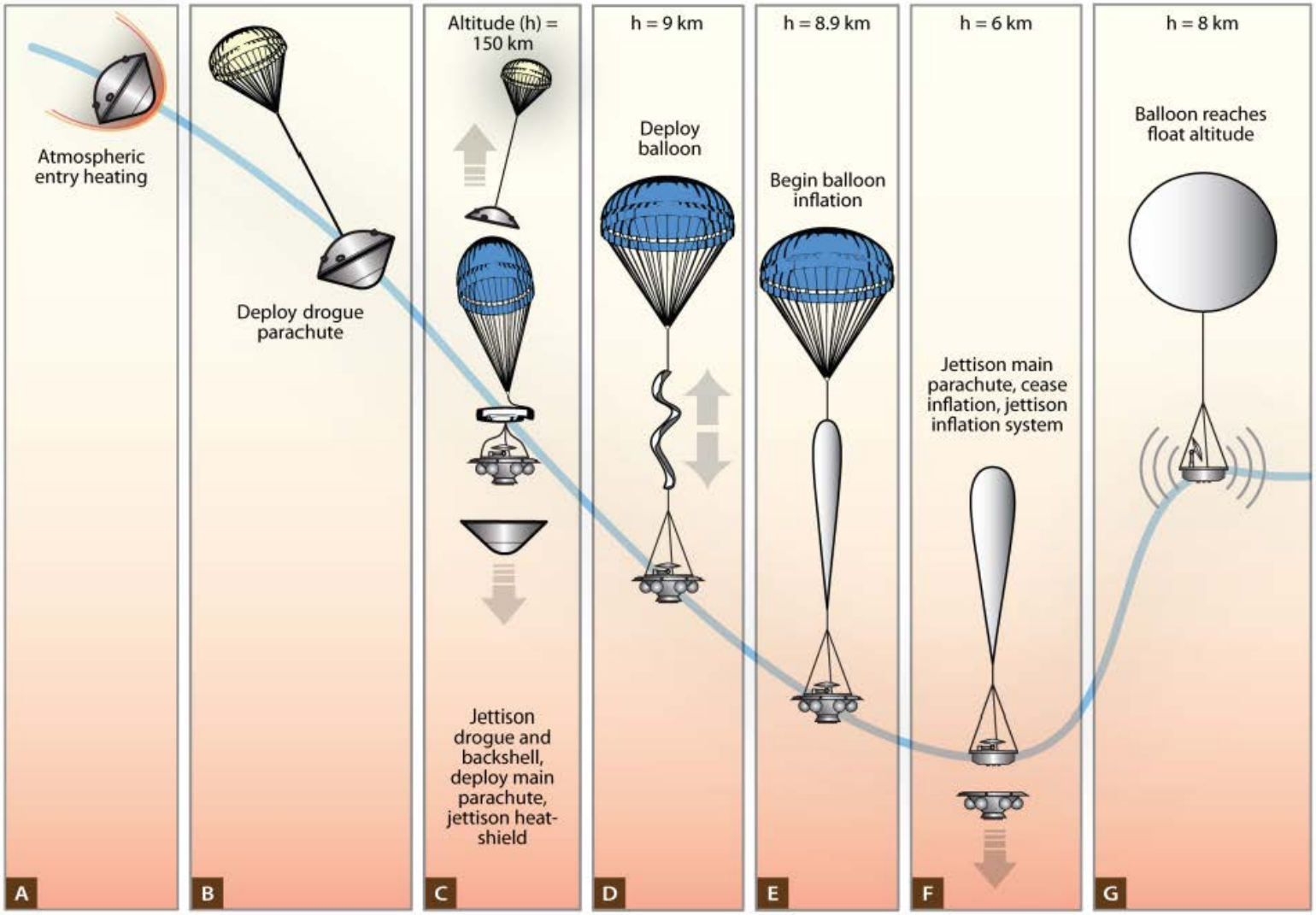
Titan Balloon Mission Concept Design

- Spherical Super Pressure Balloon 4.6 m diameter
- 1 kPa internal pressure at mission start
- Float altitude: 8 km
- 90 day minimum lifetime
- Mylar film plus fabric laminate balloon material
- 170 kg payload
- Gas venting and ballast drops accomplish altitude changes
- Aerial deployment and inflation shown on next slide

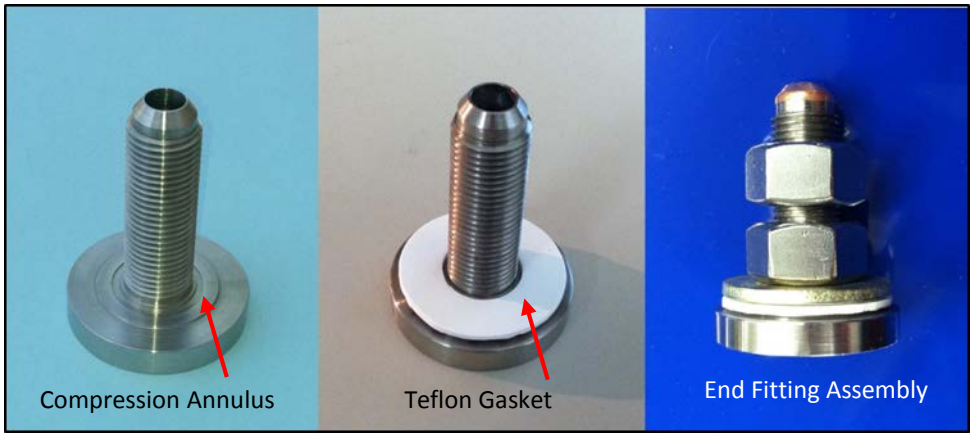
Aerial Deployment and Inflation Sequence

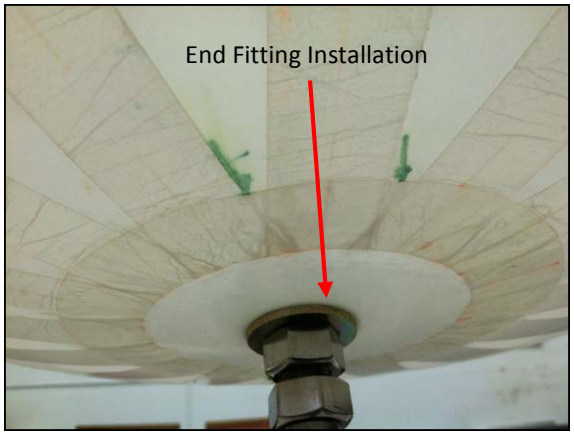


Titan Balloon Prototype Design

- Spherical Super Pressure Balloon 1.5 m diameter
- 2 to 3.5 kPa internal pressure during test
- Mylar film plus fabric laminate balloon material
- 16 gores sealed using heat activated adhesive on Mylar film tape
- Stainless steel fitting on bottom for inflation
- Expanded Teflon gasket material for end fitting seal

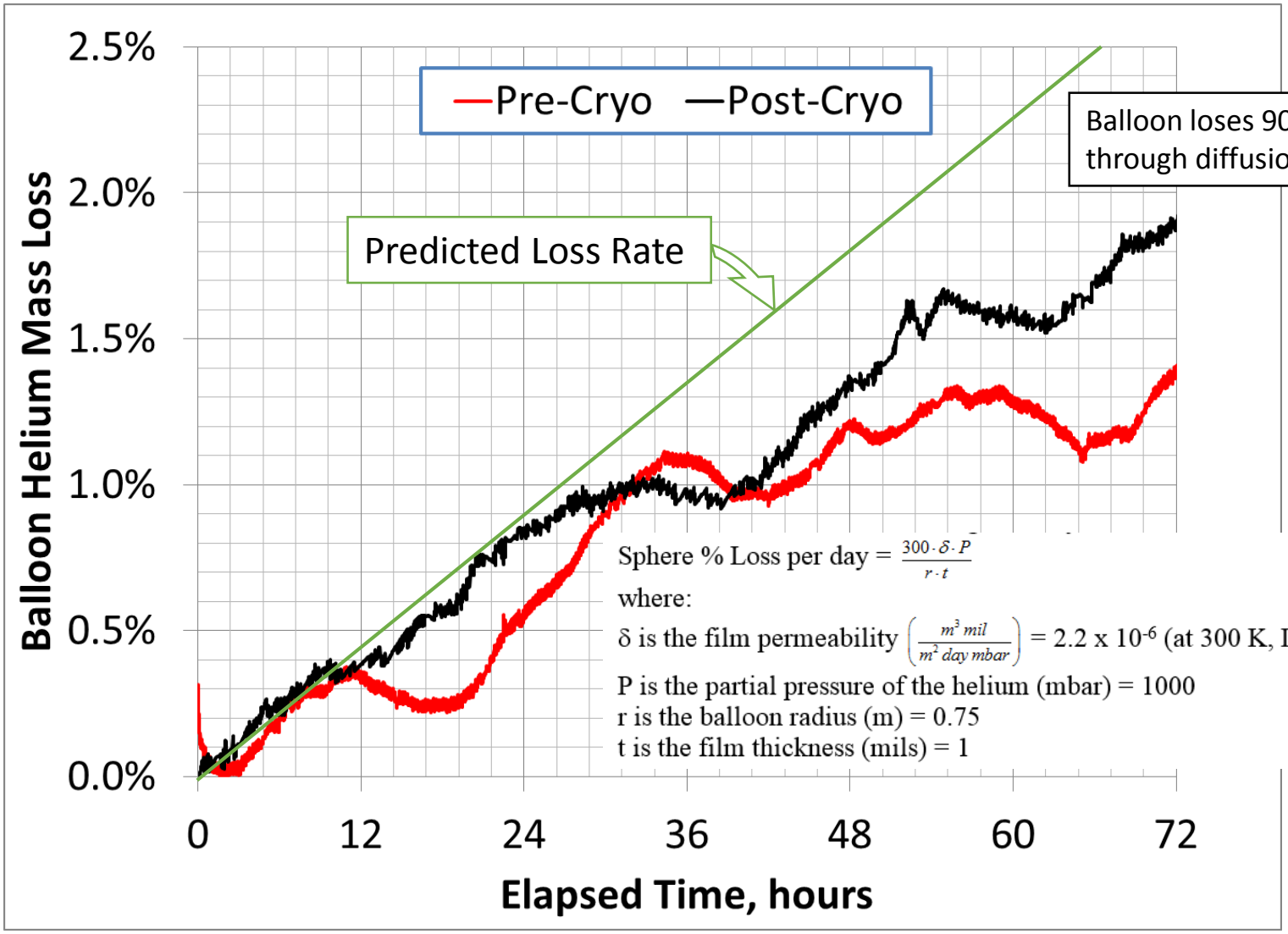
Cryogenic Balloon Fitting Seal





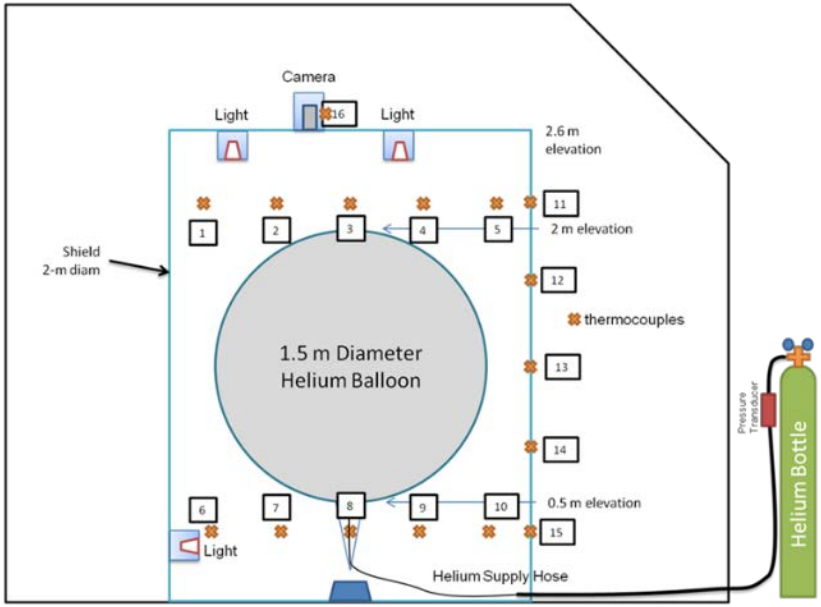
- Cryogenic systems use expanded Polytetrafluoroethylene (ePTFE) foam sheet gasket material
- ePTFE gaskets require a preload compression of 65% to provide sealing
- The sheet gasket material was 0.0625” thick - the end fitting incorporated a 0.040” raised annulus
- The CTE for the ePTFE and the stainless steel fitting are 99 and 17 ppm/K
- For ΔT = 200 K the gasket shrinks 1 mil. It can shrink by 3 mil before relieving the compression load

Ambient Temperature Helium Loss Measurements



Cryogenic Leak Testing

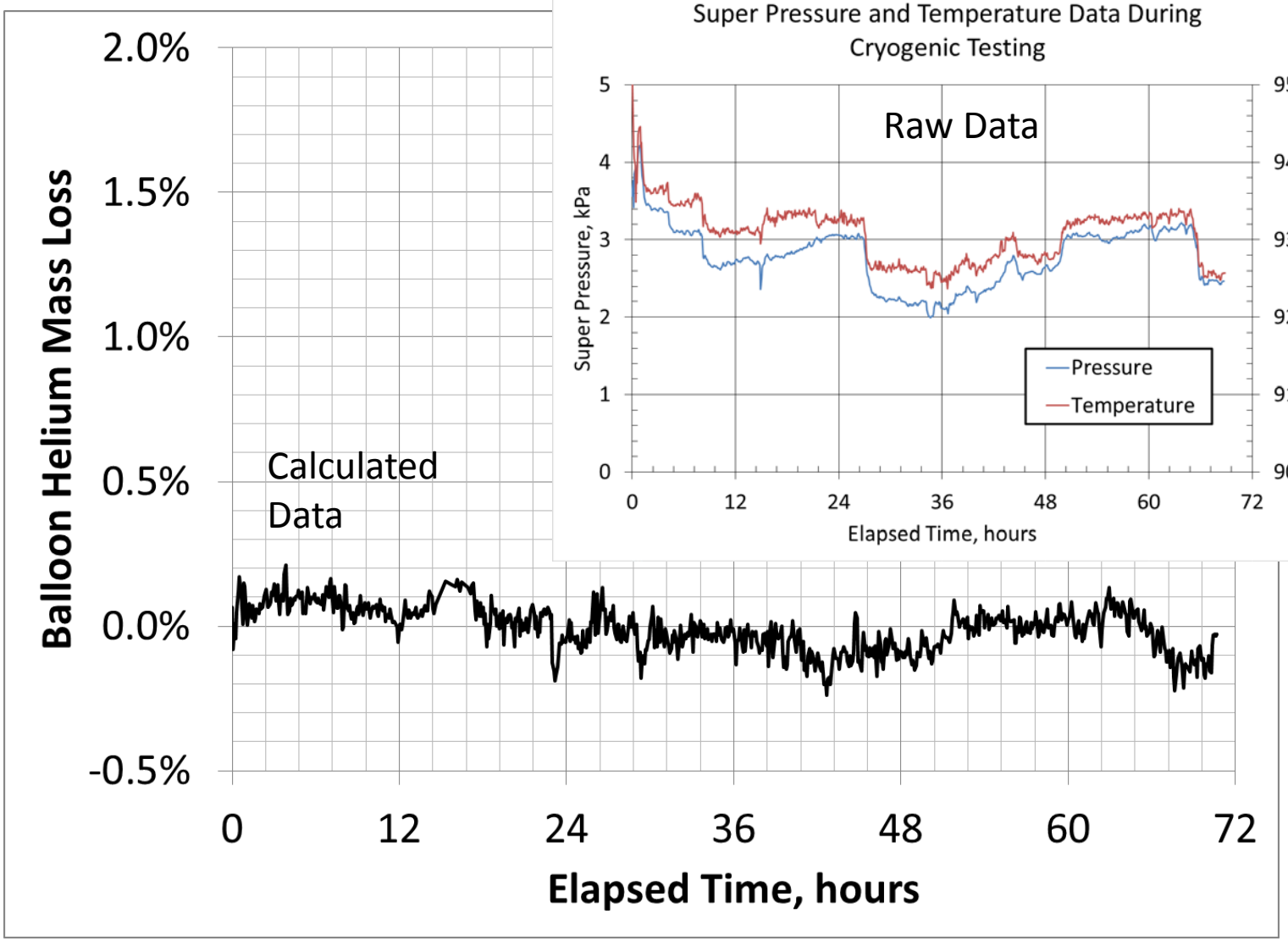
72 hours of testing at 2 to 3.5 kPa super pressure at 93 K
Monitored temperature and pressure of balloon through the test



Schematic of cryogenic test set up for the Titan super pressure balloon (approximately to scale)

Exterior of the cryogenic test chamber during operation

Helium Mass Loss During Cryogenic Testing



Conclusions

- Gas diffusion theory through a membrane predicts helium permeability is 4 orders of magnitude lower at 90 K than at 300 K
- At Titan helium loss in a super pressure balloon via diffusion is very low
- Careful handling, folding and packing the balloon reduces likelihood of developing pin hole leaks
- We demonstrated that we have developed a robust super pressure cryogenic balloon design with an ePTFE gasket for the end fitting seal
- Cryogenic testing of the balloon under super pressure (at 2-3 times the flight requirements) showed the balloon maintained constant density at Titan-like temperatures for several days

Acknowledgments
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