



# Project Loon

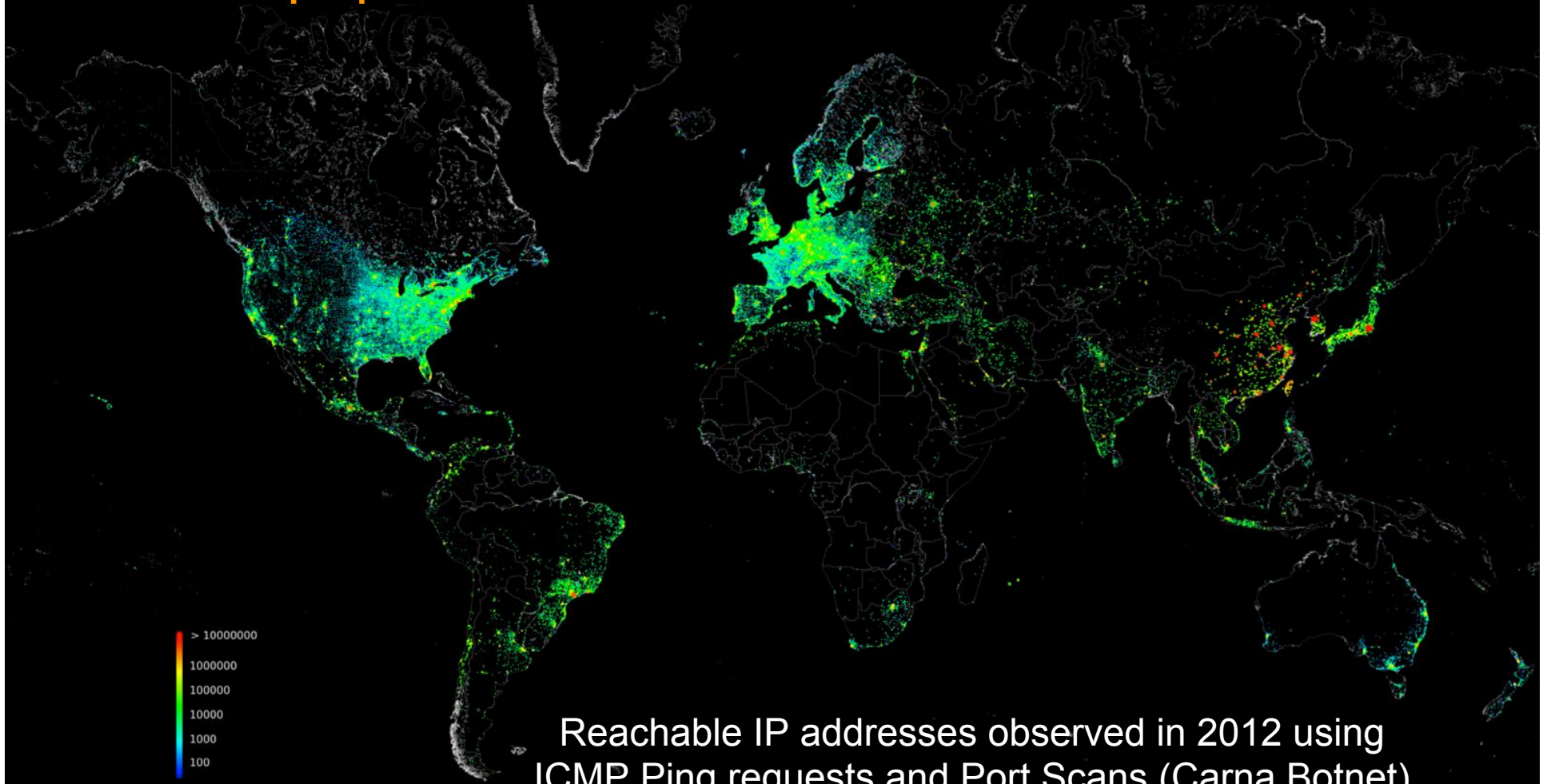
GREPECAS PPRC/4 | Lima, Peru | July 2016

**Matt Mulhern**  
Director of Loon Operations



# Internet empowers

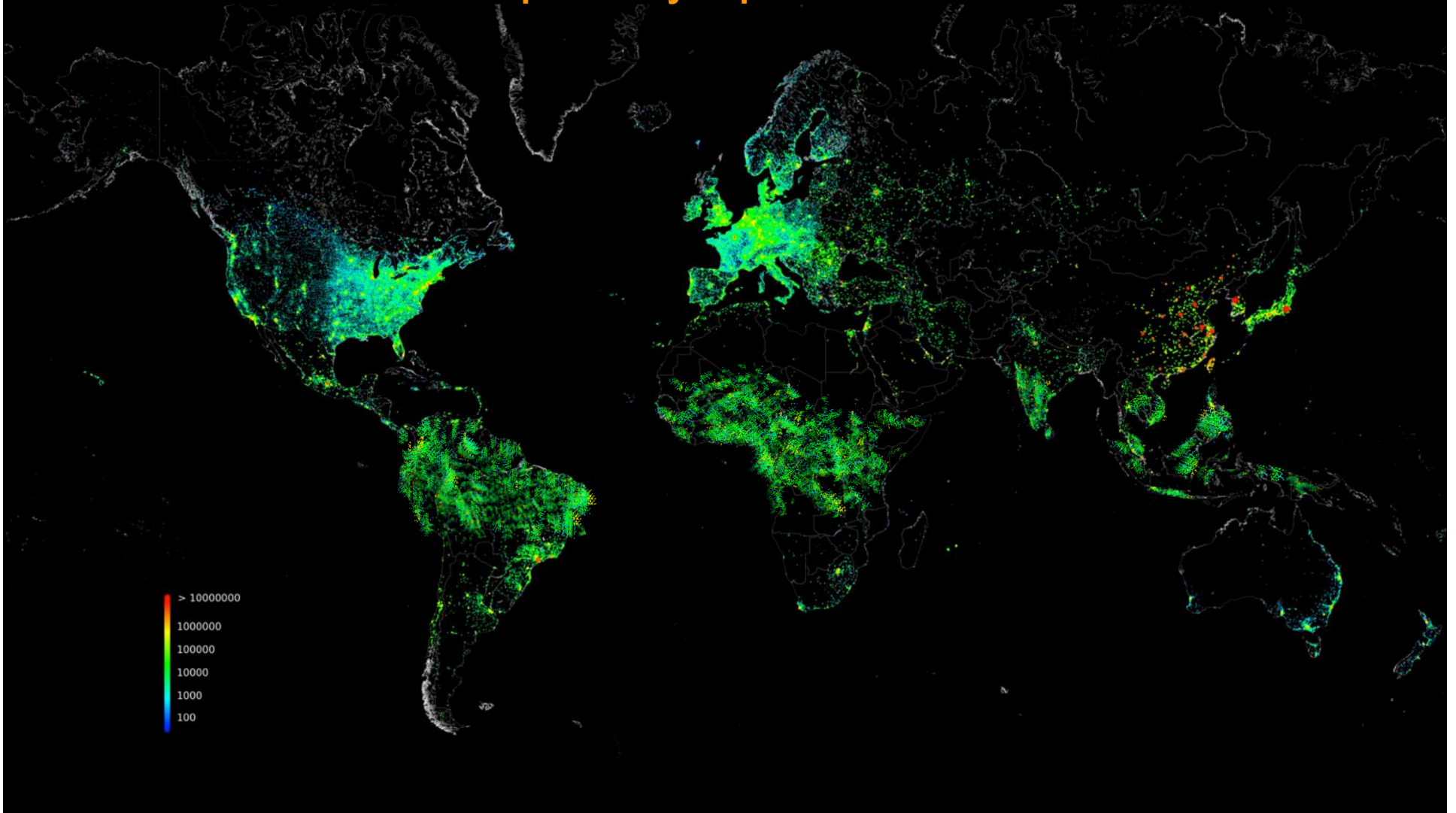
**2 out of 3 people in the world are not connected**



Reachable IP addresses observed in 2012 using ICMP Ping requests and Port Scans (Carna Botnet)

# Internet empowers

**Internet-enabled access positively impacts individuals and economies**



# 2014 LTE CONNECTION IN BRAZIL

Pilot test connected a rural school in Brazil for the first time

# Building a global network

- Circumnavigating at ~FL600, well above passenger traffic
- Operating as a network providing continuous coverage
- Using currents at different altitudes to navigate



DEMONSTRATION / VALIDATION



PROOF OF CONCEPT

# HOW LOON WORKS, AS A NETWORK



**Navigate**  
by catching currents  
at different altitudes



**Adjust as a network**  
of balloons to ensure  
continuous coverage



**Connect directly**  
to users via LTE to  
mobile device

# The balloon

*In accordance with ICAO Annex 2, Appendix 5*

## DIMENSIONS

Envelope - ~10m tall/15m wide at float  
Flight System - ~45 kg carriage

## POWER SYSTEM

Solar panels, batteries

## AVIONICS SYSTEM

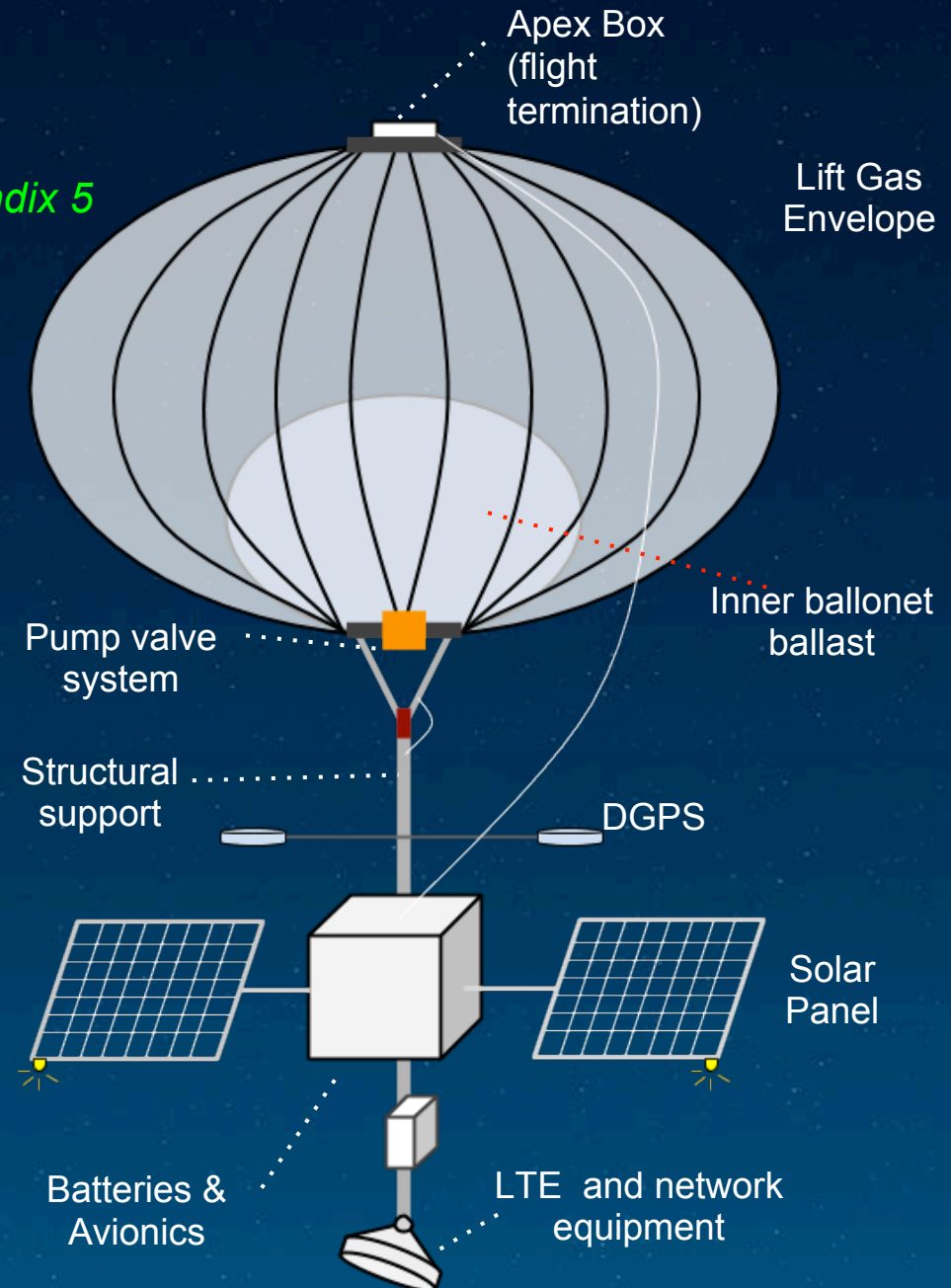
Transponder/ADS-B out, GPS + sensor state information, transmitted via Iridium

## ALTITUDE CONTROL

Pumps and valves that enable the balloon to maneuver with the winds

## DATA NETWORKING

Balloon-to-balloon and balloon-to-ground communications



NOT TO SCALE: FLIGHT SYSTEM 5X SMALLER THAN BALLOON IN HEIGHT

# Safety features

Complies with ICAO Annex 2, Appendix 5 and  
FAA Part 101, Subpart D

## VISIBILITY ELEMENTS

### Triple Redundant GNSS

1. Transponder (ADS-B out with Mode A/  
C)\*
2. Web based GPS
3. Iridium triangulation

### Radar Reflective Materials

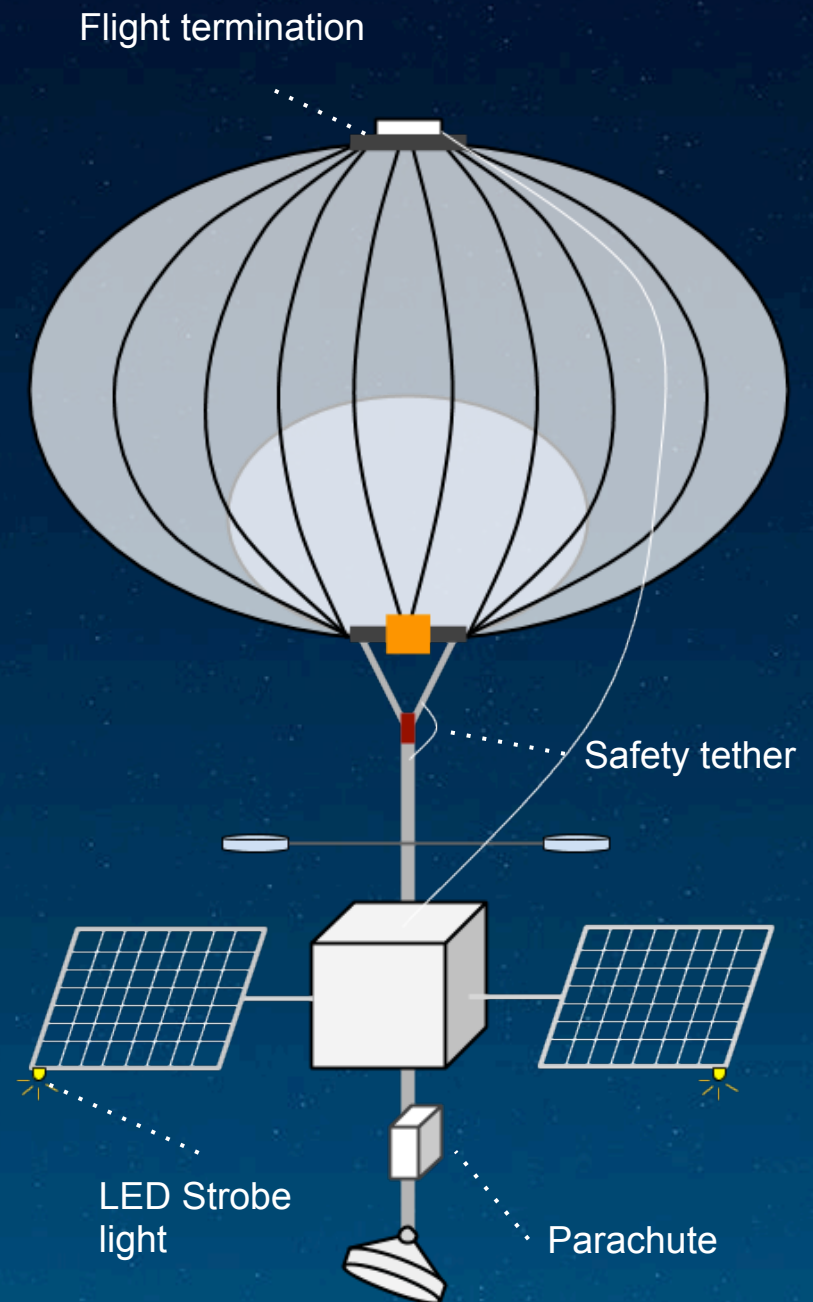
Omnidirectional light beacon ( > 5NM vis. )

## REDUNDANT FLIGHT TERMINATION

1. **Soft Terminate**  
Slow vent, ~90 minute descent time
2. **Hard Terminate**  
Quick vent, ~60 minute descent time

## THE FLIGHT SYSTEM & BALLOON STAY AS ONE

Parachute recovers flight system and balloon



NOT TO SCALE: FLIGHT SYSTEM 5X SMALLER THAN BALLOON IN HEIGHT

# Launch ( currently US based )

*In accordance with FAA Part 101, Subpart D*

**2 WEEKS  
PRIOR**

Assess Launch Site ( Wx & conditions )  
Execute flight path simulations ( winds,  
special use airspaces )

**24  
HOURS  
PRIOR**

File flight plans + NOTAMS with FAA  
Share most up-to-date wind data + accurate  
simulations

**60  
MINUTES  
PRIOR**

Final Equipment and vehicle inspections  
Final Checklist signoffs  
Coordination with Mission Control & FAA  
Fill balloon

**5  
MINUTES  
PRIOR**

Final launch coordination





# Command and control of the balloon network

## Experienced operators monitor a Geographic Information System 365 / 24

- Access to quasi real-time and historical balloon data ( 1-3 min telemetries )
- Internal training program results in operator certificate

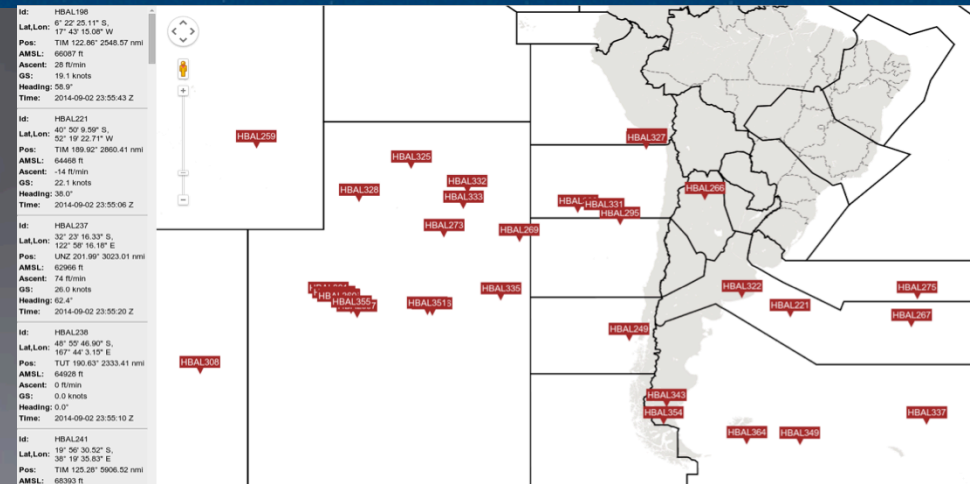
## Simulation algorithms predict future balloon positions and state

## Two-way communication allowing steering

## Continuous health monitoring enables flight duration



**Internal Fleet visualisation Interface**  
*shows quasi real time data and predictions for each balloon*



**Fleet visualisation website available to ATC**  
*shows quasi real time position and essential data to ATC*

# Transiting FIRs

Example operating procedure for coordination with ATCs

## 72 HOURS PRIOR

Flight plan to ATC in agreed upon format e.g. phone / email and then updated every 12 hours

1. Flight Identifier
2. Current Position
3. Approximate Entry Time
4. Approximate Entry Position
5. Balloon / flight system description

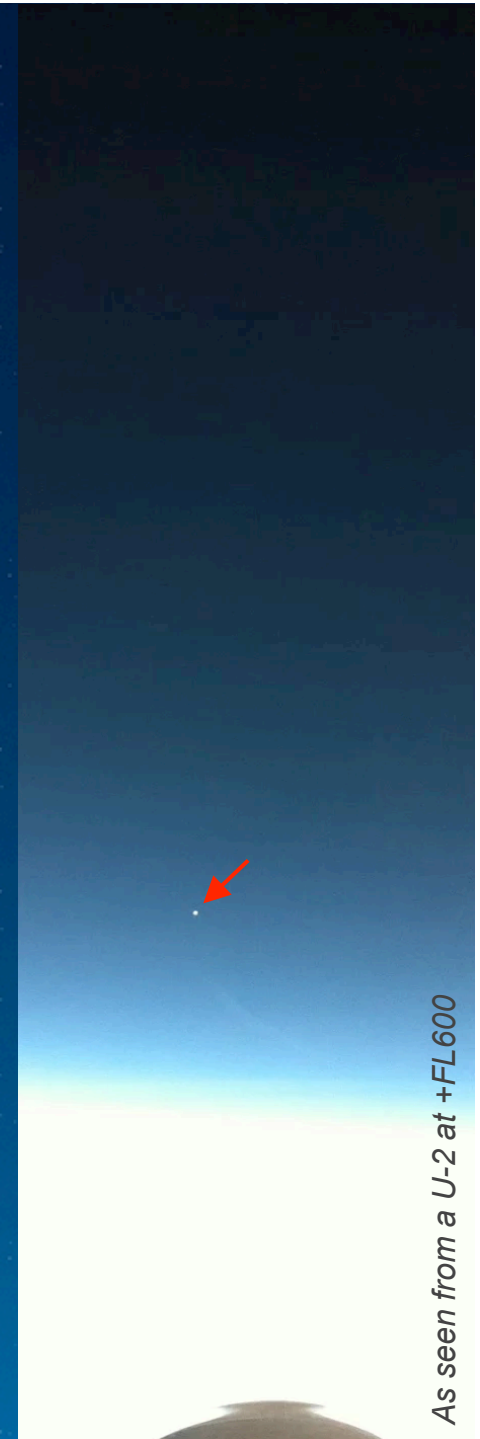
## 60 MINUTES PRIOR

50 km ( approximately 60 minutes ) prior to entry

1. Call affected FIR / ARTCC if they desire
2. Notify of any changes in flight plan
3. Provide additional info upon request

Transit occurs above 60,000 ft. In cases that we do transit below FL600, we coordinate with ATC.

**Able to tailor communications to ATC direction**



As seen from a U-2 at +FL600

# Transiting FIRs

## Google Loon

1600 Amphitheater Parkway  
Mountain View, CA 94043  
Project Loon

Loon Mission Control: Direct: +1-650-966-7655 | E-mail: LoonMC@google.com

### High Altitude Balloon Predicted Flight Path

Flight	Beacon	Altitude (ft)	Heading (d)	Speed (knot)	Current Location	ICAO
HBAL285	4453	61551	106.65	22.66	32° 41' 49.77" S 41° 55' 46.16" E	1ba1037

#### NOTAM:

Flight Tracking Website: <https://www.aerostar-faa.com> username: faa password: 99CrimsonBall@@ns

Calculated Flight Plan for HBAL285. Weather conditions can shift actual course.

Event	Time (UTC)	Altitude (ft)	Heading (d)	Speed (knot)	Latitude/Longitude
CURRENT JOHANNESBURG OCEANIC	2016-04-22 15:45	61551	106.65	22.66	32° 41' 49.77" S 41° 55' 46.16" E
ENTER MAURITIUS	2016-04-24 16:10	61539	60.30	10.60	33° 25' 43.43" S 57° 1' 1.72" E

#### LONG HAUL: TBD

Balloon Height: 8.8 m Super Pressure Balloon Diameter: 15.0 m Super Pressure Balloon Weight: 102.2 kg Super Pressure Payload Weight: 36.7 kg Parachute Length: 2.4 m Color: WHITE Transponder Equipped: YES – Mode C out. Equipped: Flashing white LED lights and radar reflectors Balloon Position: Balloon GPS position is monitored via IRIDIUM satellite telemetry



## Google Loon Flight Plan

*sent to ATC 72 hours prior to transit, during transit, and until exit*

## Google Loon Flight Path

*Internal visualization of predicted flight path*

# Landing

## SAFETY FIRST - Payload & Balloon stay as one

### SHORT TERM (R&D, Dem/Val)

- Planned 30 days in advance
- Considerations: Air Traffic, Special Use Airspace, Population Density, Infrastructure, Accessibility

### LONG TERM

- Fixed Recovery Zones
- Distributed across continents

## NOTIFICATIONS TO ATC / AGENCIES

### 24 HOURS PRIOR\*

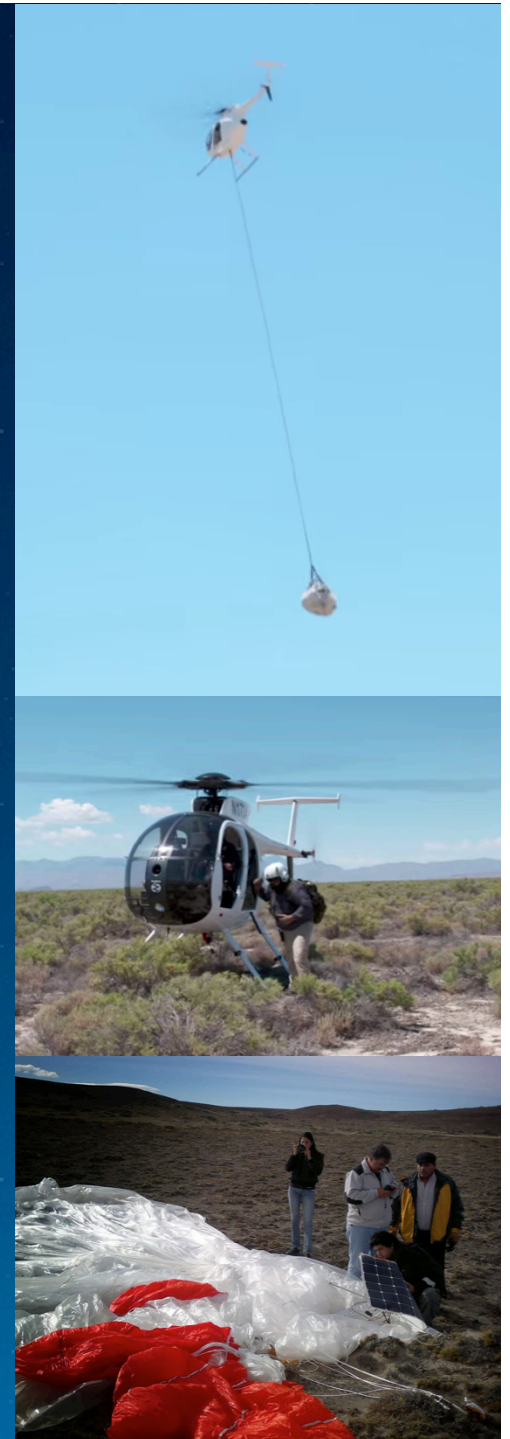
Forecasted direction of travel, rate of descent, time / location of landing, cutdown Profile  
NOTAM, if applicable

### 60 MINUTES PRIOR

Updated information of all above metrics, as necessary

### AT TIME OF CUTDOWN

Updated information of all above metrics, as necessary







Joon  
for all