# THE RISE AND FALL OF THE JIMSPHERE: A HISTORICAL PERSPECTIVE AND A LOOK FORWARD



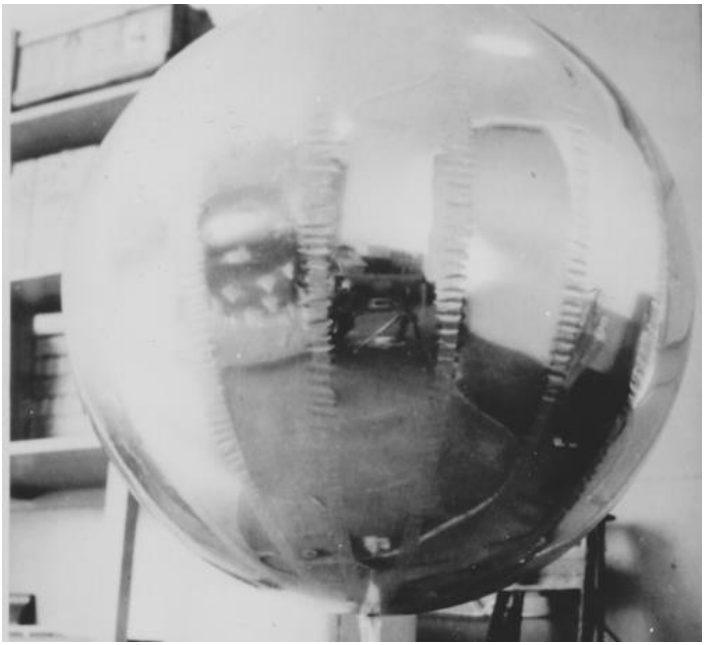
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# Why develop a new balloon system?

- In the early 1960s more detailed winds aloft information was needed for vehicle design
- Two approaches were tried
  - Photogrammetry of visible smoke trails
  - Radar tracking of a rising sphere
    - ❖The "Rising Observational Sounding Equipment" (ROSE) already existed
    - ❖Two-meter sphere with opposing vents to maintain a constant super-pressure
    - ❖Failed to provide accurate small-scale measurements due to aerodynamic instability of the sphere



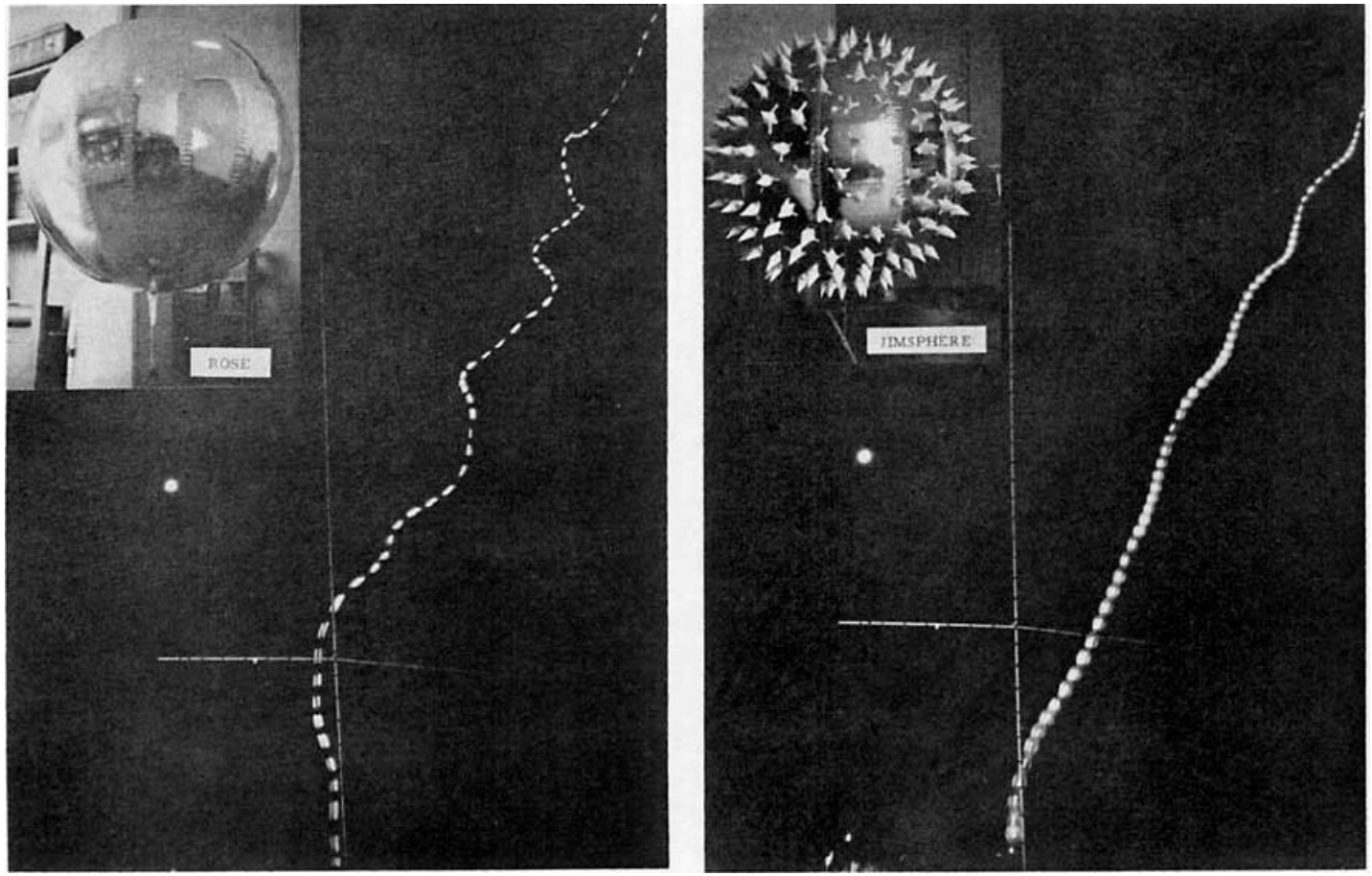
# Effects of adding roughness elements

- When a ***smooth*** sphere rises or falls through the atmosphere, a lateral, self-induced motion occurs due to aerodynamic forces that depend on the Reynolds number:

$$Re = \frac{\rho v d}{\eta}$$

- At super critical Re, below about 12km, self-induced motions are erratic and occur over a broad band of frequencies

- Right: Time lapse imagery of a smooth (left) and roughened (right) ROSE balloon released at 11:52 and 11:54 on 2 August 1963. Scoggins (1965)




ρ is the air density, ν is the ascent speed, d is the balloon's diameter, η is the viscosity of the air.

# The final jimsphere design

- Two meter sphere with 398 roughness elements, 7.6 cm high
- Opposing vent valves maintain a super-pressure of 6-8 hPa.
- The radar tracked version has 100g of ballast to lower the center of gravity and reduce spurious motion
- In the GPS version, the ballast is replaced with the GPS sonde
- The rise rate
  - About 5.4 $ms^{-1}$ at sea level
  - Decreases linearly to 4.5 $ms^{-1}$ at 15km where a more rapid decrease begins
- Max altitude in an hour is about 18 km





- Early jimspheres were radar tracked (left)
- The AMPS HRFE (right) introduced in the late 1990s uses GPS technology

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- Flight Characteristics
  - Rise rate is ~5.4 $ms^{-1}$ at sea level, and decreases linearly to 4.5 $ms^{-1}$ at 15km where a more rapid decrease begins.
  - Induced spiraling oscillation period is ~4.7 sec or about 22 to 25 meters in altitude.
  - Max altitude in an hour is about 18 km.

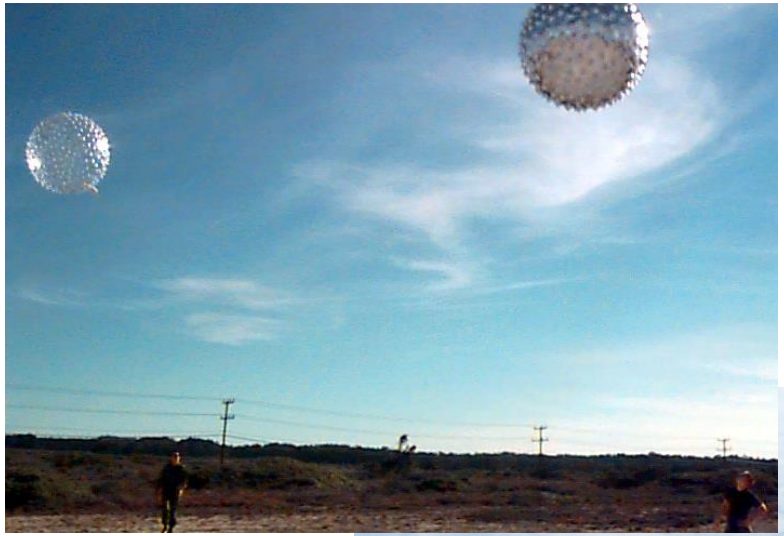




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# How do we evaluate balloon wind performance?

- Dual radar tracks of original jimspheres.
- Simultaneous releases of like balloons
- Ensemble averages of numerous (~30) releases
  - Wind differences yield precision estimates
  - Spectral and cross spectral analysis to determine noise floor and Effective Vertical Resolution (EVR)





# Radar tracked jimsphere performance

- The raw radar tracking data are processed with the ROSE program
  - Produces 100 foot averaged winds at 100 foot increments.
  - Increases averaging layer in 100 foot increments to 400 feet as radar track deteriorates.
- Wind precision is 0.5 to 0.7 $ms^{-1}$ and Effective Vertical Resolution is 200 m for most tracking conditions.
  - Radar precision
  - The 100 foot averaging layer allows some aliasing of the natural oscillation.



# The Automated Meteorological Profiling System (AMPS)

- Replaced ground based tracking with GPS technology (late 1990s) with a tech refresh by Lockheed-Martin in 2013
  - Ground Element (GE) : hardware and software that receives and controls the processing of the telemetry data stream.
  - Two types of Flight Elements (FEs), each with a unique filter
    - ❖ High Resolution (HRFE): A clear jimsphere balloon with a wind only sonde
    - ❖ Low Resolution (LRFE): Standard latex rawinsonde balloon & full sonde

| | Precision ($ms^{-1}$) | Effective Vertical Resolution (m) |
|---|---|---|
| HRFE | <0.5 | 160 |
| LRFE (21.3m) | 1.1 | 300-400 |
| LRFE (30.5m) | 1.3 | 350-450 |





# The fall of the jimsphere?



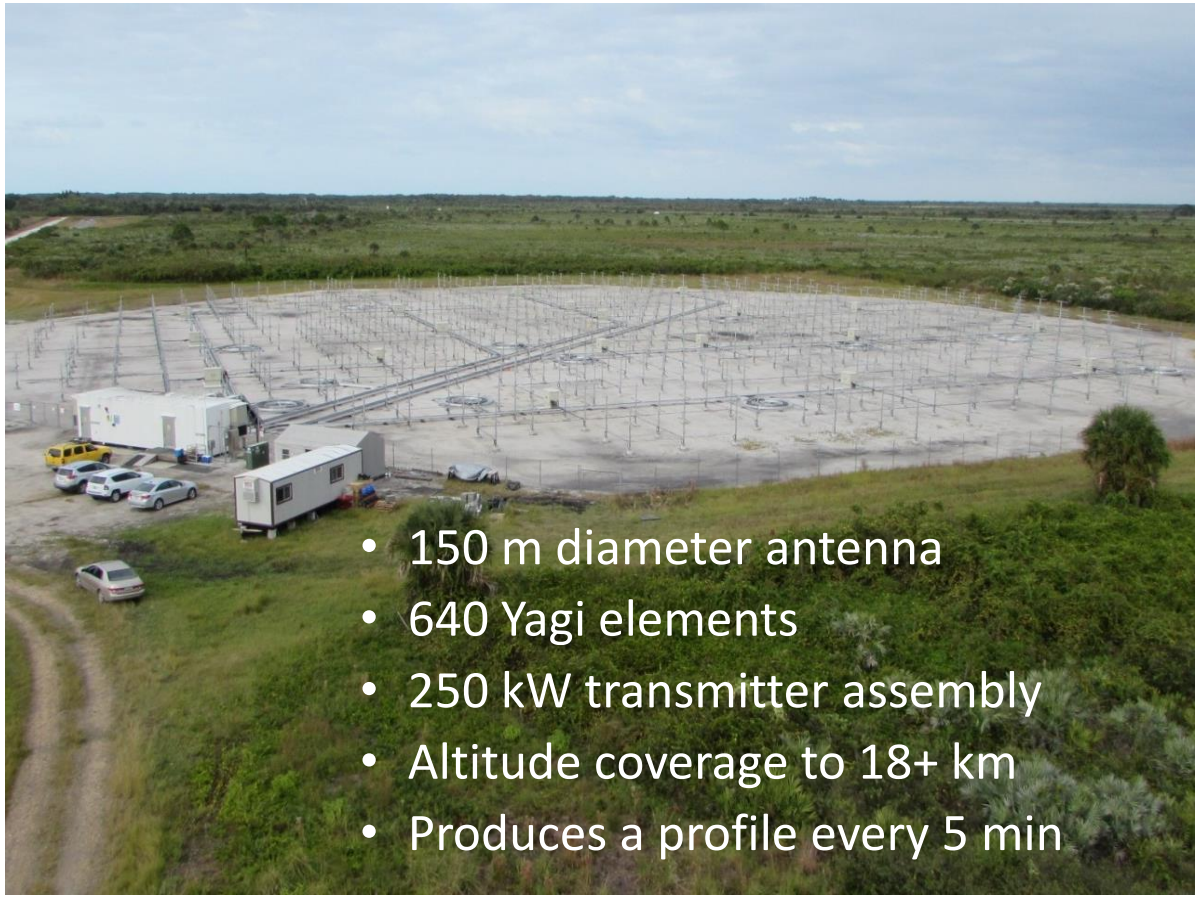
- The AMPS HRFE balloon – the clear jimsphere
  - Is expensive
  - Requires a different processing filter from standard rawinsondes
  - The AMPS system is no longer supported by Lockheed-Martin
  - High precision measurements are not critical for DOL operations
- Many launch programs are using standard rawinsondes; however
  - All Balloons drift with the wind and may not represent overhead conditions
  - Balloons take an hour or so to reach 18 km





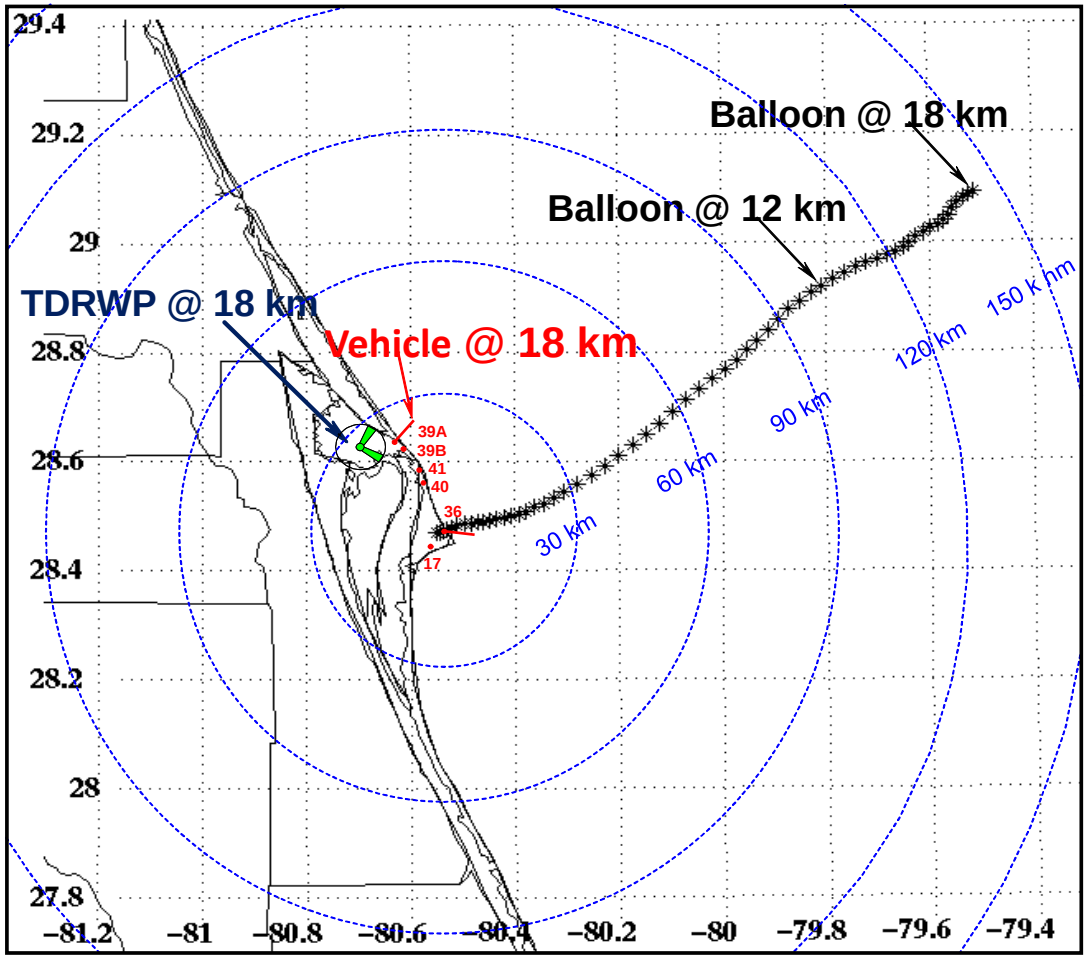
# The NASA TDRWP

- Initial configuration at 49.25 MHz had a range resolution of 150 m
  - Balloon component differences were ~2 $ms^{-1}$, correlated to downwind distance
  - EVR was Nyquist limited at 300 m
- Interference with HAMs required performance compromising changes
  - Now half power at 48 MHz
  - Two different pulse configurations
    - ❖ EVR of 450m
    - ❖ EVR of 330m; but at further reduced power
- Return to near original performance possible with hardware filters.



# TDRWP vs Balloons

- **Balloon & profiler data are from different places** since balloon blows downwind
- **Balloon and profiler data can differ significantly, yet both be correct**
- Profiler provides data more representative of flight path winds
- Several DOL cases where the profiler detected wind changes that later were reflected in the balloon profiles



# A Note on Vehicle Loads

- Each type of vehicle has a known *capability* to withstand launch loads. Margins (knockdowns) are defined for possible dispersions in such things as vehicle manufacturing, thrust, as well as uncertainty in the wind changes between the last measurement and T-0 (wind persistence or more accurately, *impersistence*).
- The vehicle steering program is developed based on measurements prior to T-0 or climatology.
- Changes in the wind profile between the steering wind profile and measurements taken later on DOL cause additional vehicle loads, reducing launch availability.

# Wind Characteristics: Temporal Change Probability

- The probability distribution of mid-tropospheric wind changes is **Lognormal**, not Gaussian
  - rapid large wind changes occur **much more frequently** than expected based on a Gaussian assumption.
  - For example, the "3-sigma event" is about **13 times** more likely (0.0171 vs. 0.00135).
- References
  - Merceret (1997a): Rapid temporal changes of midtropospheric winds, *J. Appl. Meteor.*, **36**, 1567-1575.
  - Merceret (1997b): Risk assessment consequences of the lognormal distribution of midtropospheric wind changes, *J. Spacecr. Rockets*, **35**, 111-112.

# Summary: Upper air measurements for DOL support







| | HRFE – Jimsphere | Rawinsonde | NASA TDRWP |
|---|---|---|---|
| **Precision** | <0.5 m/s | 1.1 m/s | 1 m/s |
| **EVR** | 160m | 300-400m | 300-450m |
| **Max Altitude** | 18 km | 30km | 18km |
| **Measurement Time** | 1 hour | 1 -2 hour | 5 min |
| **Pros** | precision | less expensive | frequent measurements<br>measures overhead |
| **Cons** | expensive<br>sonde obsolete<br>drifts downwind | drifts downwind<br>precision | initial cost<br>precision<br>performance compromised |