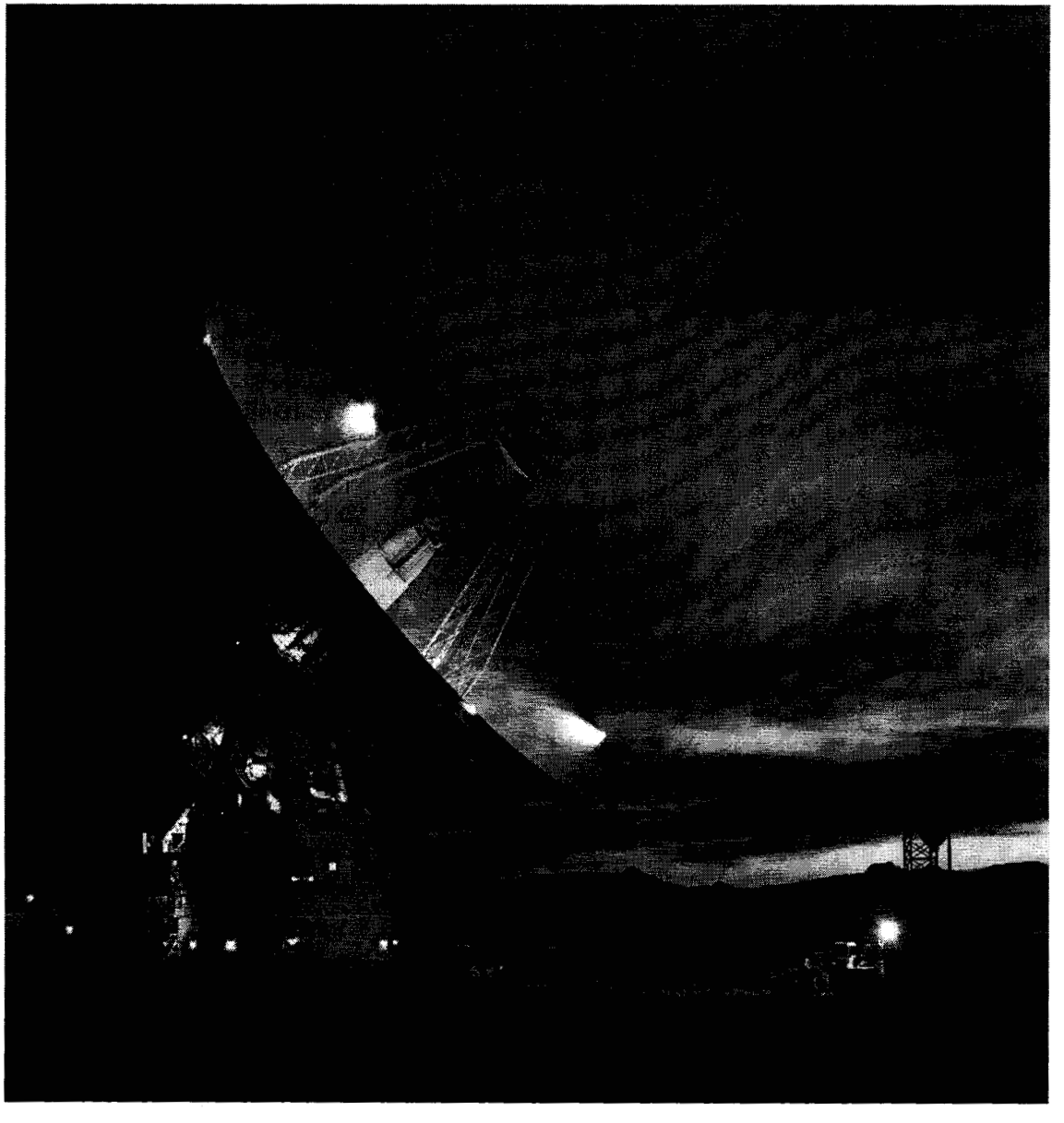
Interplanetary Network Directorate



Operational Demonstration of Ka-band Telecommunications for the Mars Reconnaissance Orbiter

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Outline

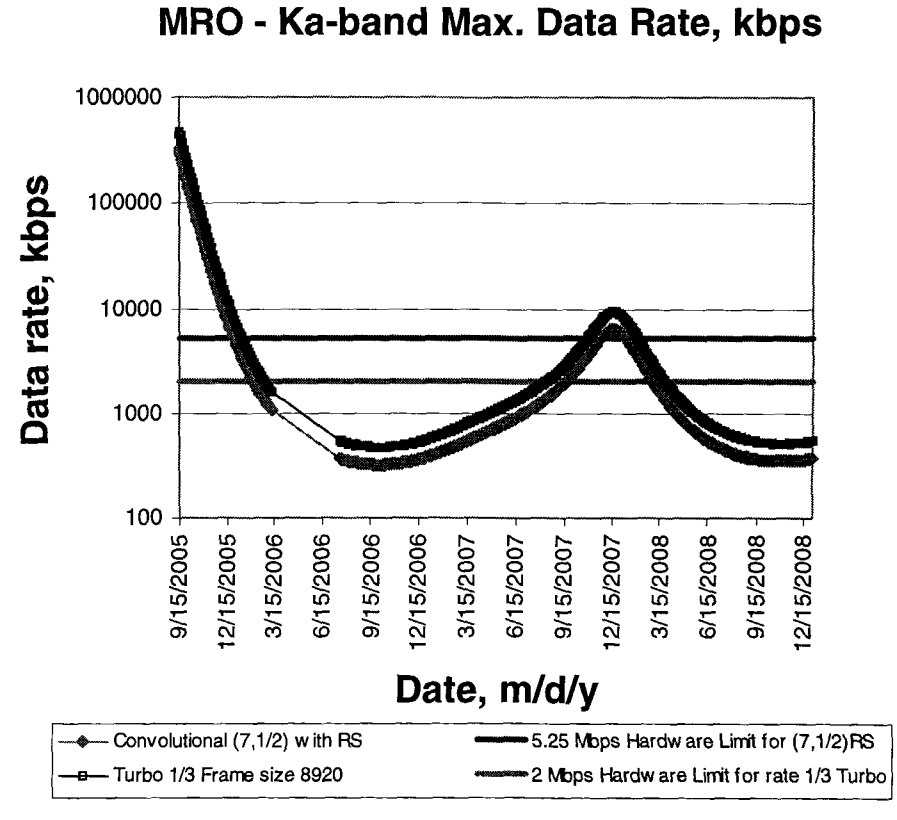
- Introduction
- Objectives of Demonstration
- Weather
- Weather handling
- What we plan to do with MRO

Why Ka-Band?

- **Bandwidth**
  - **Ever increasing data rates from solar system missions**
    - **Goal of 10-100 Mbps from Mars within 10 years**
  - **50 MHz X-Band (8.40-8.45 GHz) allocation for downlink**
  - **500 MHz Ka-Band (31.8-32.3 GHz) allocation for downlink**
- **Performance**
  - **All things being equal on both ends of the link, just changing the frequency theoretically improves link performance by a factor of ~16 (12 dB)**
  - **Previous studies have shown that we could realistically expect a factor of at least 4 (6 dB) when accounting for lower efficiencies, pointing losses, etc. at Ka-band**

Objectives of MRO Ka-Band Demonstration

- Demonstrate formal procedures for operating Ka-band links
  - Predicts and sequence driven
  - Minimal "joysticking"
  - Includes both ground and space
    - Ground antenna pointing, and other hardware system performance will be demonstrated
  - Fine tune these procedures for future missions based upon the outcome of this demonstration
- Demonstrate up to 5.25 Mbps data rate when the links will allow
  - Cruise and Mars closest approach
  - (7,1/2) convolutional coding concatenated with (255,223) Reed - Solomon coding
- Demonstrate the effectiveness of wideband Delta-DOR at Ka-band
  - 38.4 MHz at X-band
  - 153.6 MHz at Ka-band
- Acquire data about performance at solar conjunction

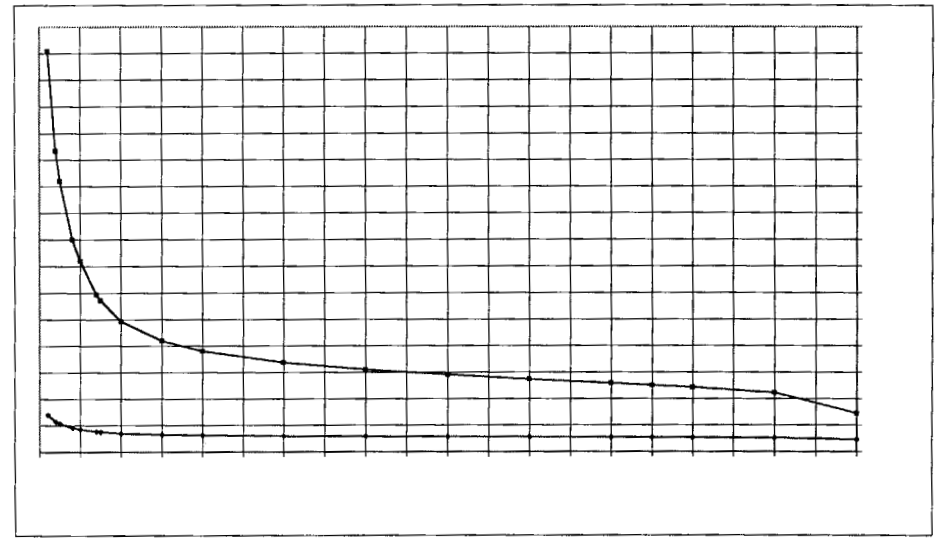


What About Weather?

- The single most important uncontrollable element in the performance of Ka-band links is the effect of weather manifested by
  - Reduced data return
  - Reduced link reliability
  - Disruption of data continuity
  - Data incompleteness
- Operations strategies must be developed to mitigate these effects or or at least optimize performance relative to them
- The MRO Ka-Band Operations Demonstration will investigate these operational considerations
  - Must live within the limitations of cost and interference to the science mission
  - Complexity of the required operations procedures becomes an important factor

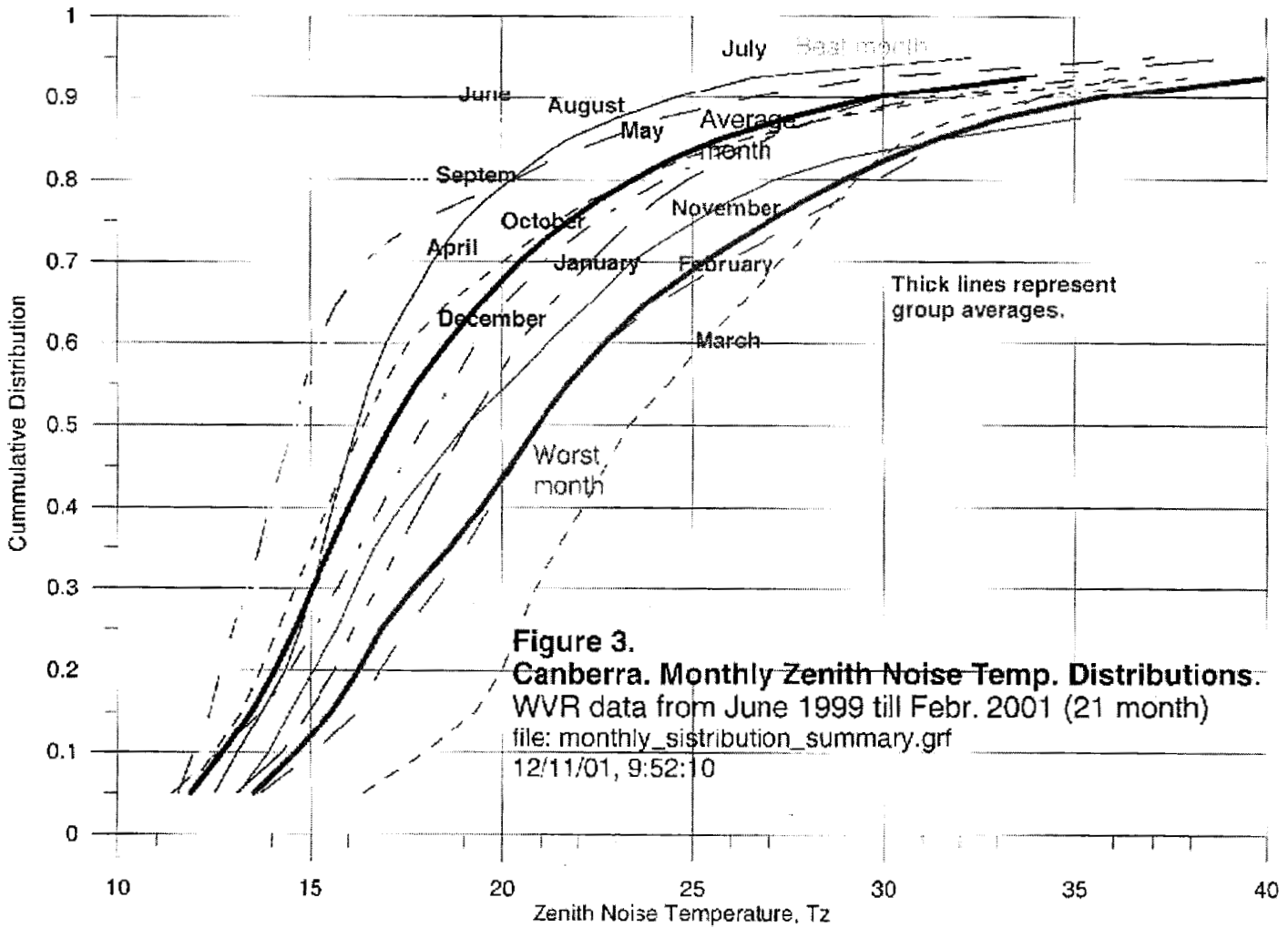
What We Do at X-Band

- Weather enters into our link budgets as a contribution to the receive noise temperature above and beyond the electronics system temperature
- We use an estimated cumulative distribution function
  - Long-term average
  - Month-to-month variations are not that great
  - Find the noise temperature value below which we will be 90% (or 95%) of the time for our link budgets



Ka-Band Atmospheric Temperature

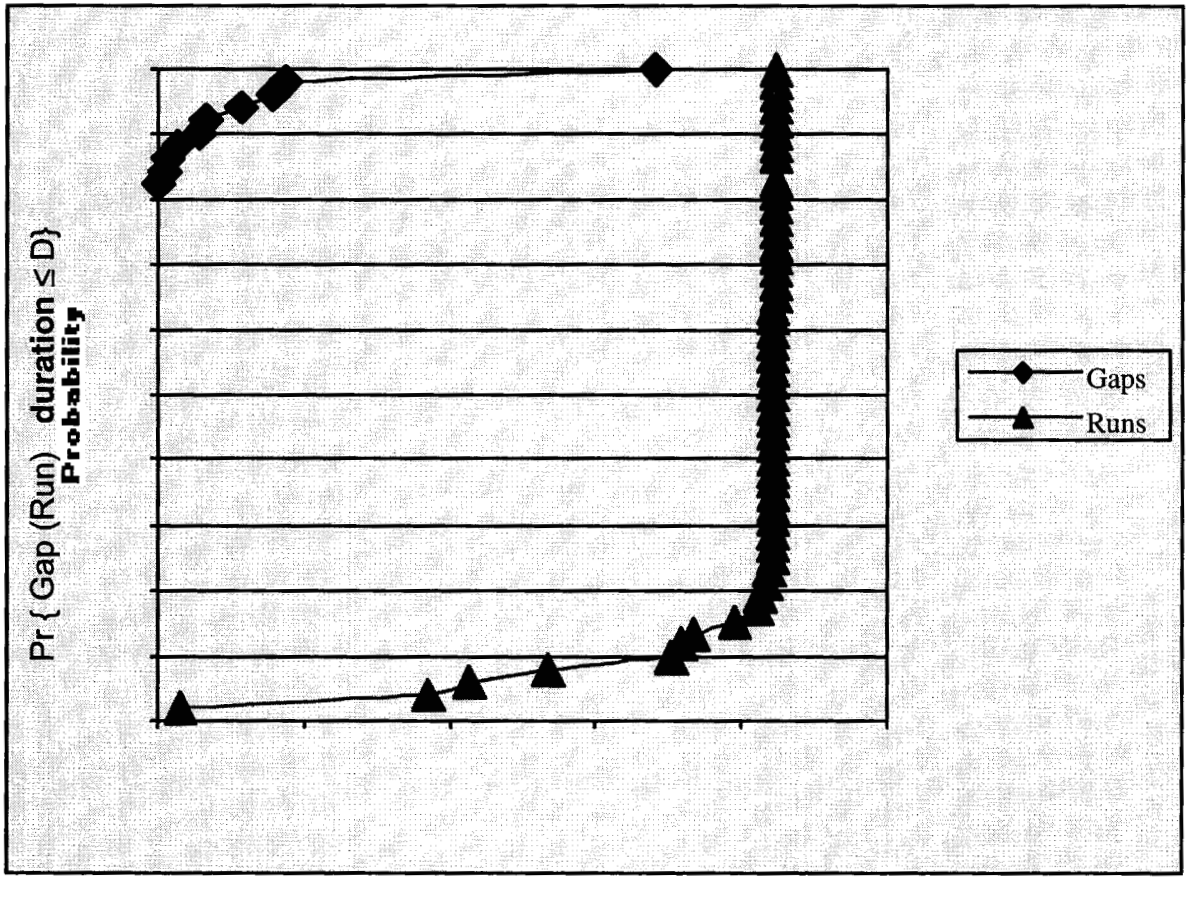
- **Ka-band atmospheric noise temperature is much more variable**



Courtesy of Alex Mileant

Data Gaps

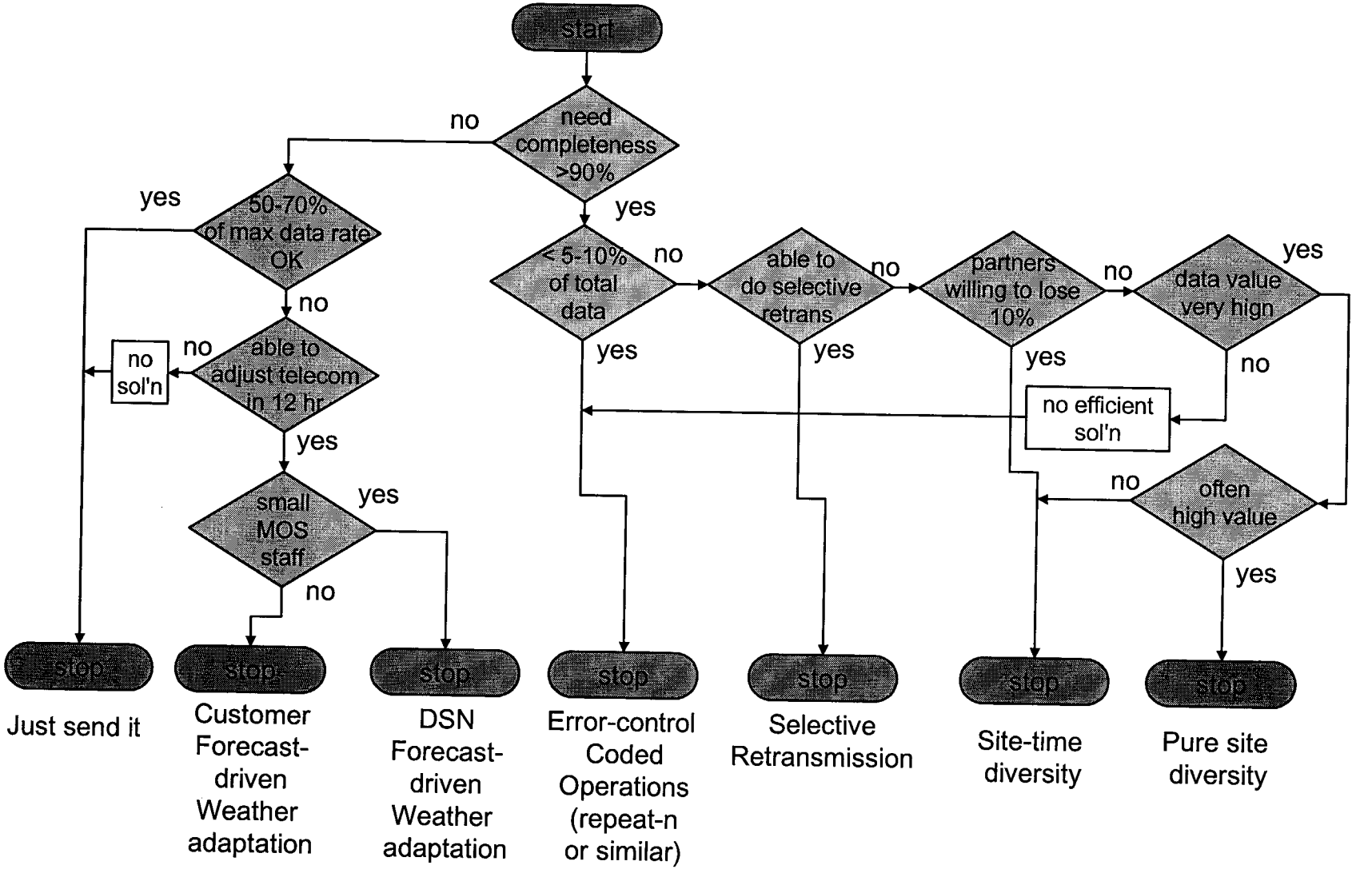
- **In the short-term during one pass, the weather effects are manifested in varying length runs of good data separated by varying lengths gaps of lost data**



Weather Handling Strategies

- **Just Send It**
  - No attempt is made to adapt to weather in the short-term
  - Predictions are made on longer-term weather statistics
- **Diversity**
  - Site--receive stations are far enough apart to have independent weather and yet the spacecraft can see them at the same time
  - Site-Time--identical downlink occurs at more than one station but stations do not have to be visible to the spacecraft at the same time
- **Selective Retransmission**
  - Determine what data was missed in a particular downlink and retransmit on the next downlink
- **Forecast-Driven Adaptation**
  - Adapt the downlink data rate to the weather conditions for a pass
- **Error control**
  - Use an error control coding strategy that can handle comparatively long gaps in the data

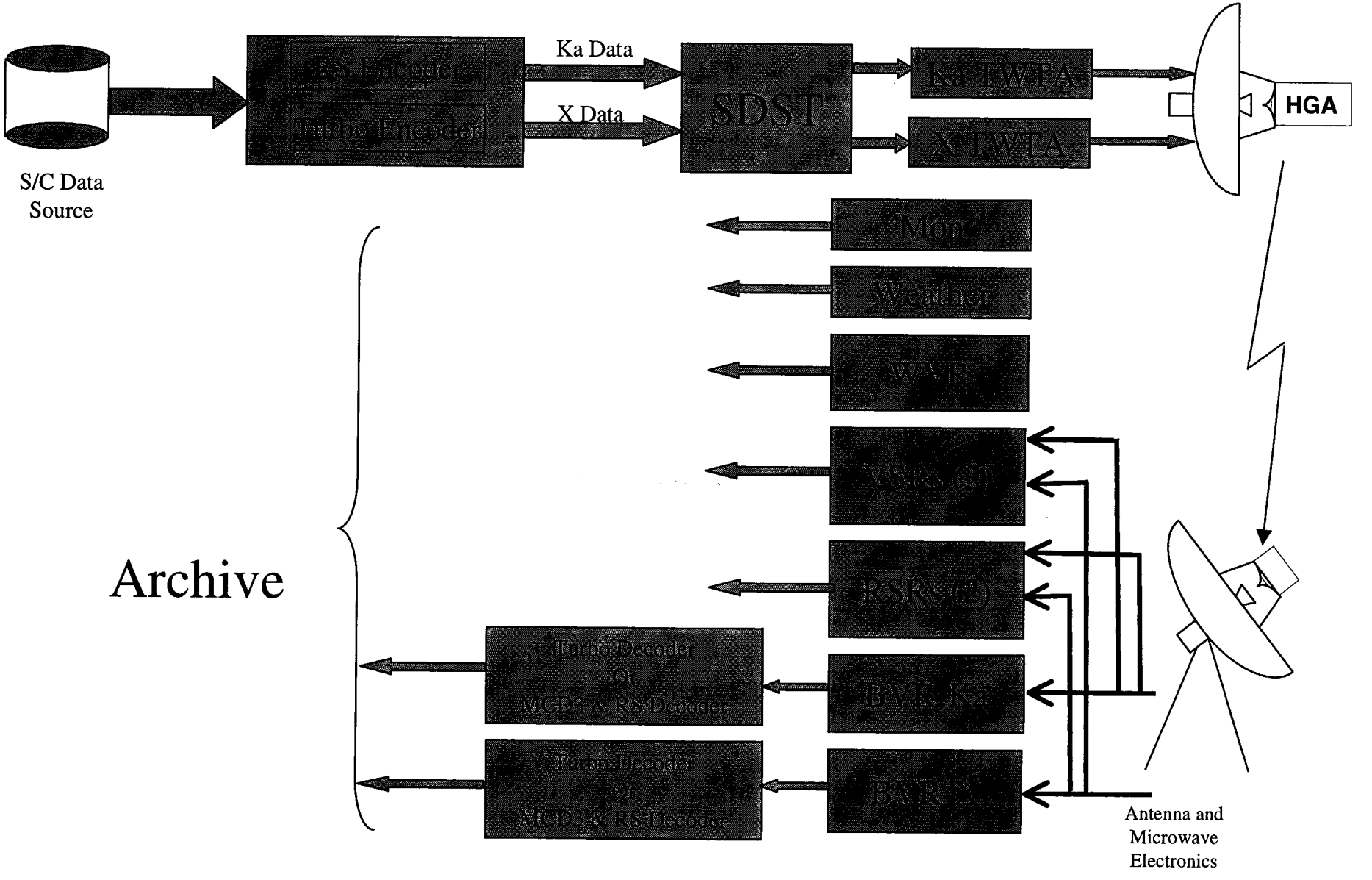
Strategies for Handling Weather at Ka-Band



Techniques to be Tried On MRO

- For MRO we will be able to try:
  - Just Send It
    - We will be varying data rates, thresholds and elevation angles at which we begin and end our tracks to try to optimize throughput
  - Selective Retransmission
    - MRO has a retransmission strategy that will allow retransmission of missed data--details still being worked
    - Will not have too much freedom to optimize this ourselves though we will have input into the development
  - Error control
    - Simple block repetition of data (repeat-N) spaced far enough apart to hopefully get at least one repetition through
    - Also can be looked at as time diversity
  - Forecast-Driven Adaptation
    - Try to update link budgets prior to the pass (allowing for propagation delay to Mars)
    - Limited by cost and complexity of such "real-time" commanding

Experimental Setup for MRO Demo



Summary

- Upcoming NASA missions like Kepler, James Web Telescope and Mars Telesat will be moving to Ka-band to support the higher data rates needed
- The MRO Ka-Band Operations Demonstration will give us experience with long term operations at Ka-band
  - Try the procedures that we can subject to cost, complexity and non-interference to science mission
  - Measure and quantify performance and Ka-band statistics
  - Fine tune and propose new procedures for the future