Effects of Clouds on Optical Imaging of the Space Shuttle During the Ascent Phase: A Statistical Analysis Based on a 3D Model

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Paper 6.5: 11th ARAM; 6 October 2004

Task driven by the Columbia Accident Investigation Board Report

- *"Upgrade the imaging system to be capable of providing a minimum of three useful views of the space shuttle from liftoff to at least solid rocket booster separation, along any expected ascent azimuth.*

- *The operational status of these assets should be included in the launch commit criteria for future launches.*

- *Consider using ships or aircraft to provide additional views of the shuttle during ascent."*

Goals

- Provide Objective Guidance on Response of Imaging Performance to Upgrades of Camera System
- Determine Sensitivity of Imaging Performance to Variations in Cloud Cover and Required Number of Simultaneous Views

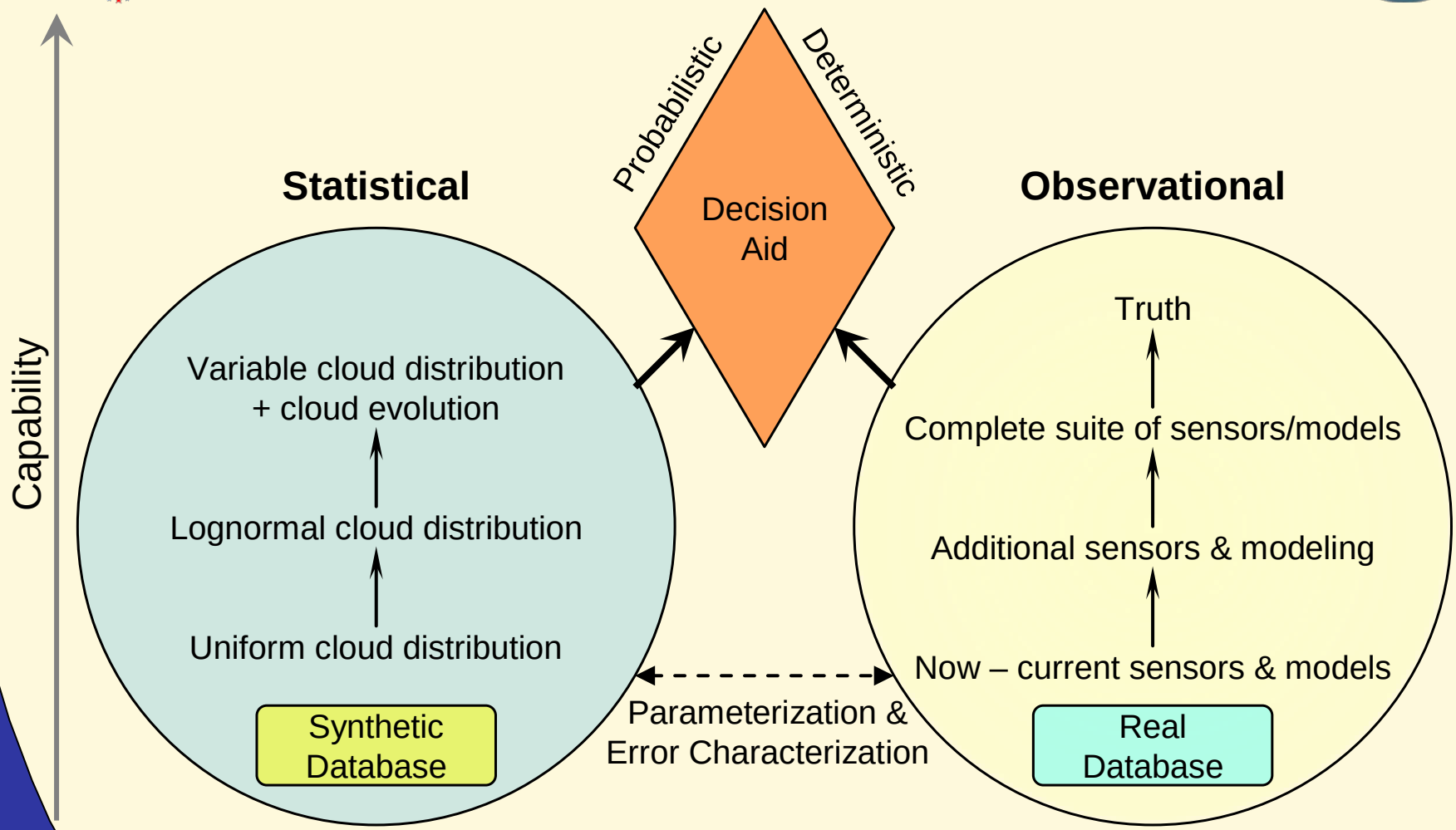
Team Members

- KSC Launch Director
- Applied Meteorology Unit
- 45th Weather Squadron
- NASA Intercenter Photo Working Group
- KSC Ice and Debris Team
- KSC Weather Office

Milestones

- Aug 03: CAIB Report Published
- Sep 03: AMU Options Study
  - *Shuttle Imaging Weather Evaluation Concept Study*
- Oct 03: AMU Options Study Complete
- Nov 03: Team Selected Statistical Method vs. Observational
- Nov 03 – Mar 04: AMU Performed Statistical Analysis
- Mar 04 – Jul 04: Briefings to Return-to-Flight Engineering Review Boards
- Oct 04: 11th Conference on ARAM

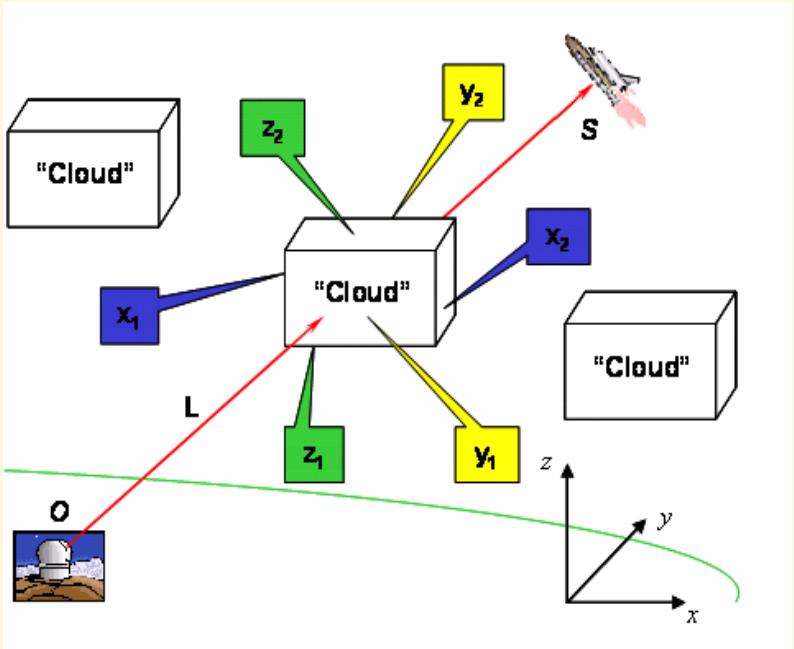
Potential Solutions



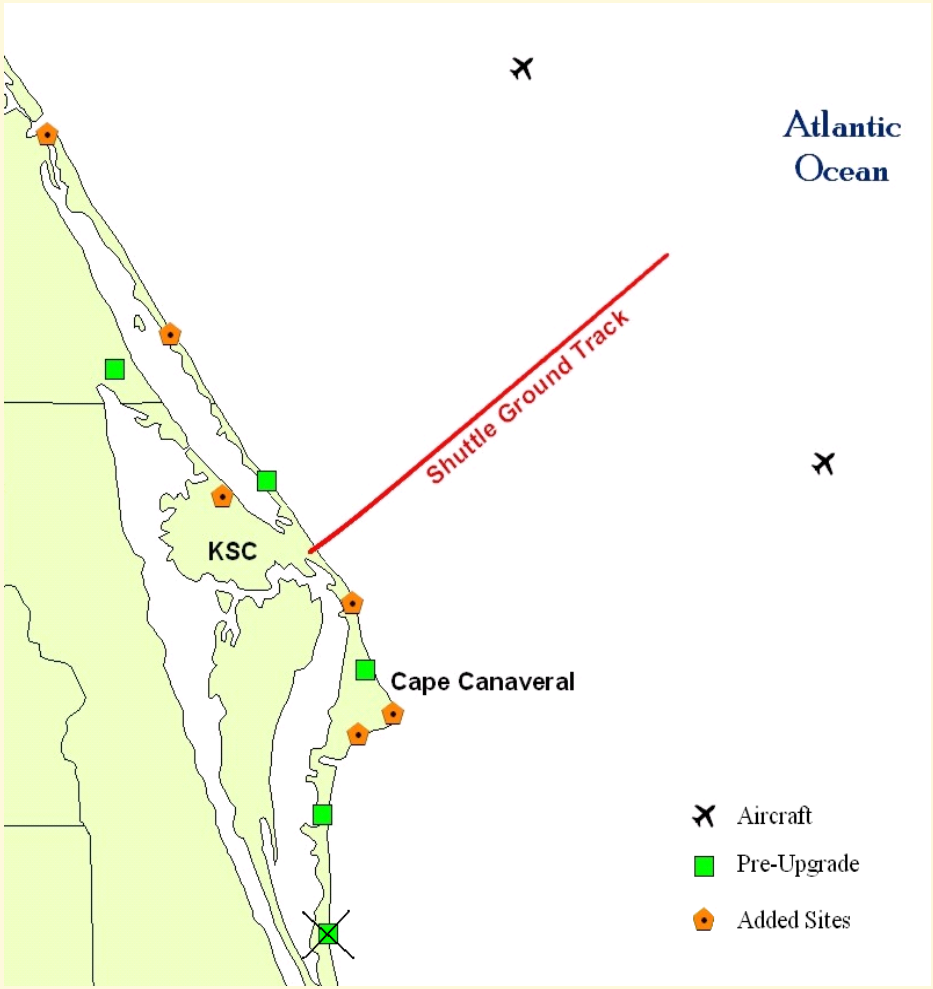
What we did

- **Task: Assess Impact of Clouds on Shuttle Imaging**
- **Statistical Approach**
  - Statistical modeling of cloud field
    - 1000 simulations each for cloud cover from 1/8 to 7/8
    - 124 sec flight time: to Solid Rocket Booster (SRB) separation
  - 3-D cloud model
    - Randomized locations of uniformly sized cloud elements
  - International Space Station ascent trajectory
  - Camera locations and capabilities (long-, medium- and short-range)
- **Statistical Analyses**
  - % of time of ascent from lift-off to SRB separation with n-simultaneous views
    - Prior to and after upgrade of camera system
    - Including with and without 2 airborne cameras
  - Cloud base 8000', cloud thickness 500', coverage: clear → overcast

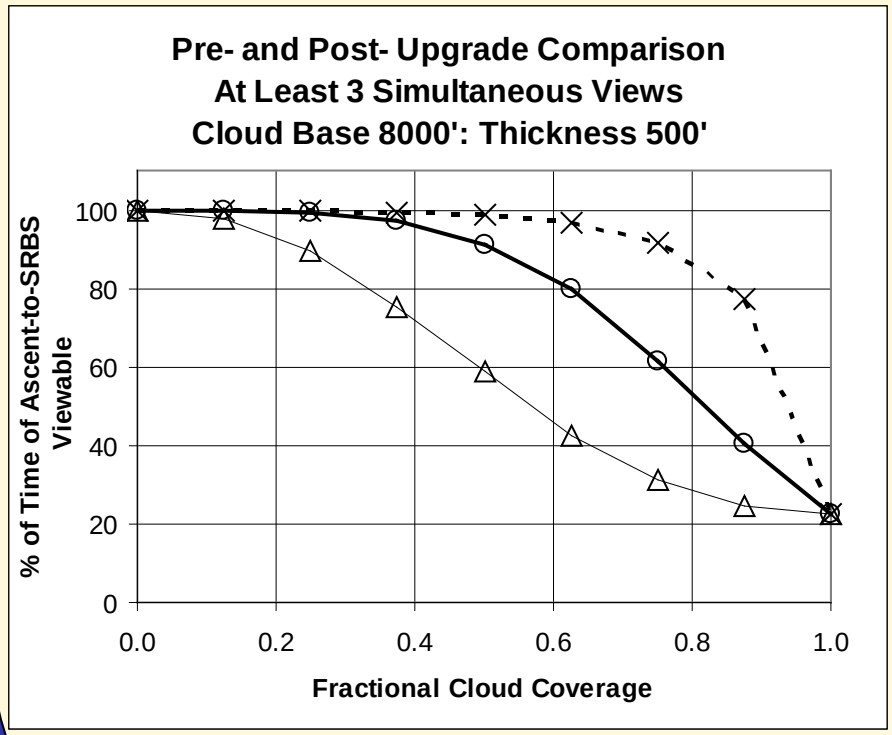
3D Model Domain & Camera Locations

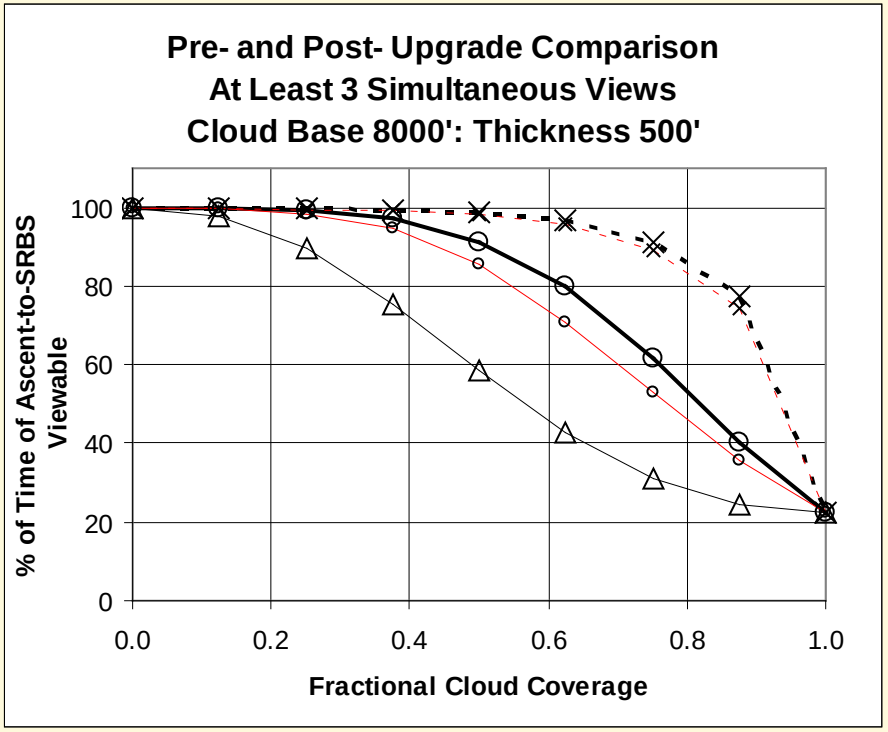


O - Long Range Camera Site
L - Line-of-sight to Shuttle Launch Vehicle
S – Shuttle Launch Vehicle
Random Cuboidal Cloud Elements
(sizes: 1, 4, 8, 16, 32 n mi)



Effect of Clouds on Total Camera Network
[Max: 10 Long-Range Cameras (5 North and 5 South)]
[—— : 8 Long-Range Cameras (4 North and 4 South)]



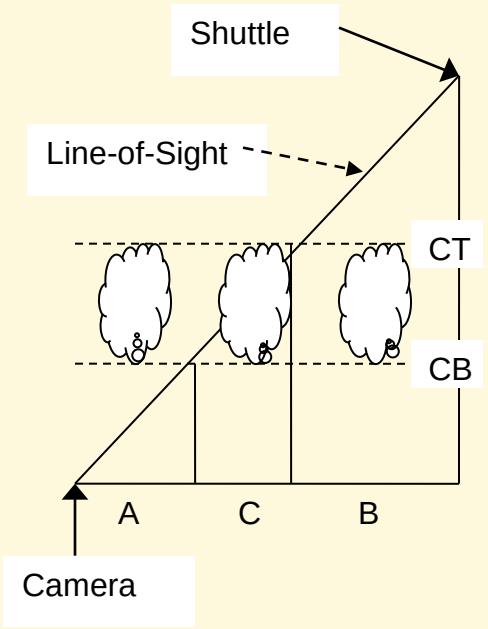


- - - - X - - - - Post-upgrade, with airborne cameras

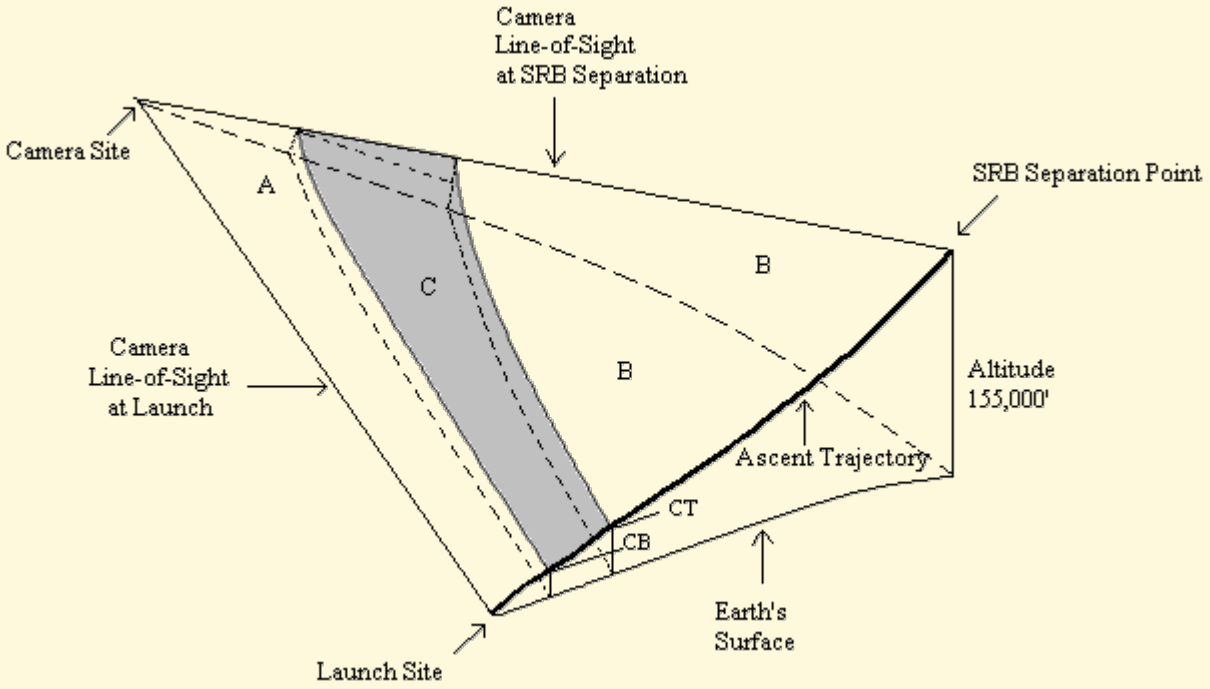
——O—— Post-upgrade, no airborne cameras

———△——— Pre-upgrade, 5 long-range cameras

Mapping Potential Cloud Obscuration Zones

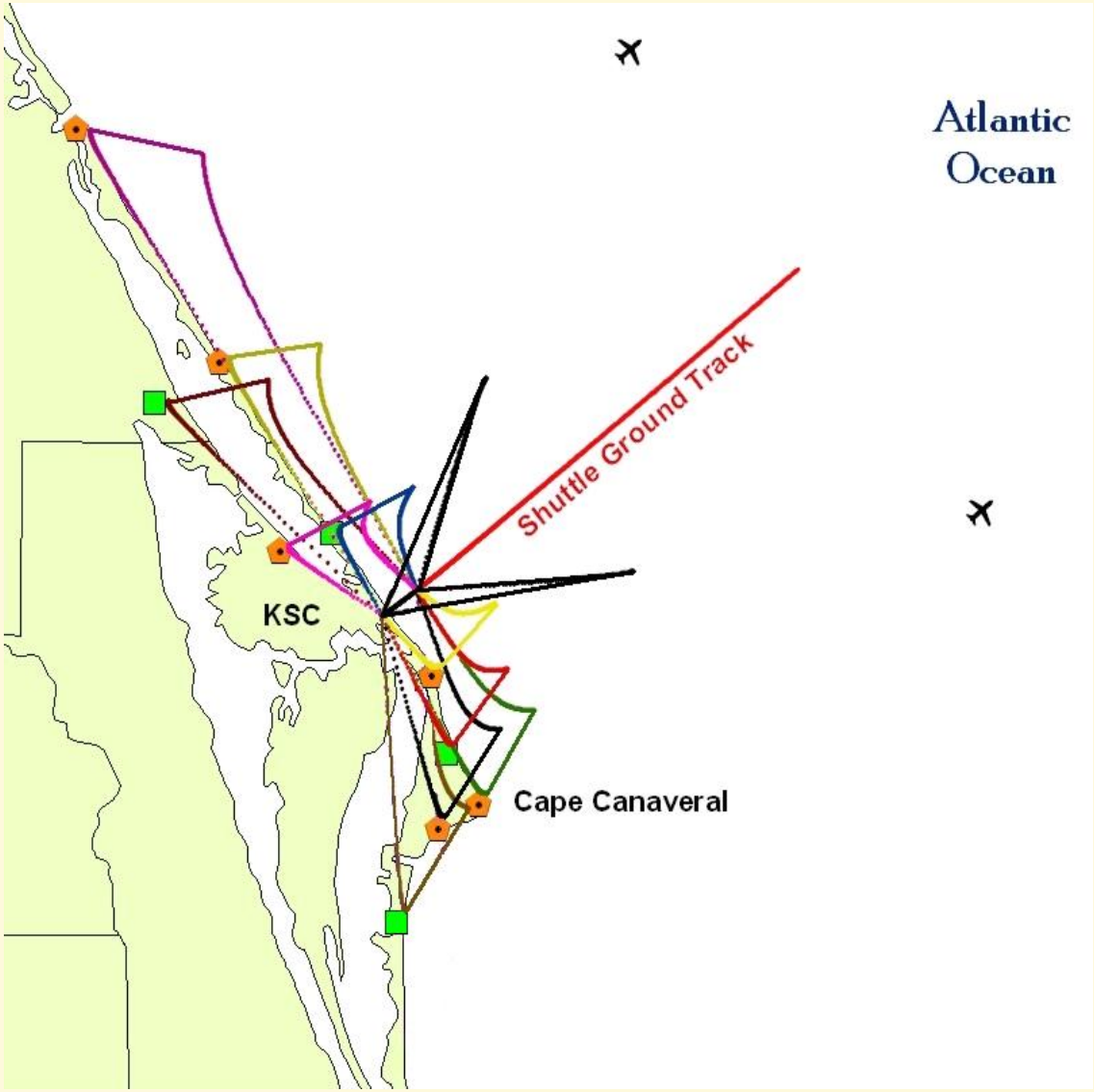


Single Line-of-sight
A – LOS below cloud
C – LOS obscured
B – LOS above cloud



Line-of-sight and Cloud Obscuration Zone (C) for one camera throughout ascent phase to SRB separation

Mapping Potential Cloud Obscuration Zones
Base = 3000’
Top = 27 000’



Summary

- Determined Method—Probabilistic vs. Deterministic
- Developed and Ran Statistical Model, Analyzed Output
- Presented results at Return to Flight Engineering Review Board Meetings; March, April, May, June and July 2004
- Future: Possible development of GOES overlay displaying area where clouds have impact on cameras