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

David A. Short and Robert E. Lane, Jr.: Applied Meteorology Unit/ENSCO, Inc., Cocoa Beach, FL
Katherine A. Winters
45th Weather Squadron, Patrick Air Force Base, FL
John T. Madura
NASA/Kennedy Space Center/Weather Office, FL

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

Statistical
- Variable cloud distribution + cloud evolution
- Lognormal cloud distribution
- Uniform cloud distribution

Deterministic
- Complete suite of sensors/models
- Additional sensors & modeling

Probabilistic
- Truth
- Now – current sensors & models

Decision Aid

Synthetic Database

Real Database

Parameterization & Error Characterization
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)]

Pre- and Post-Upgrade Comparison

At Least 3 Simultaneous Views

Cloud Base 8000': Thickness 500'

Fractional Cloud Coverage

% of Time of Ascent-to-SRBS

Viewable

Pre-upgrade, 5 long-range cameras

Post-upgrade, with airborne cameras

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