Project Orion Abort Flight Test

Evaluation of the Orion Pad Abort 1 Flight Test Objectives

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Two Definitions and the Agenda

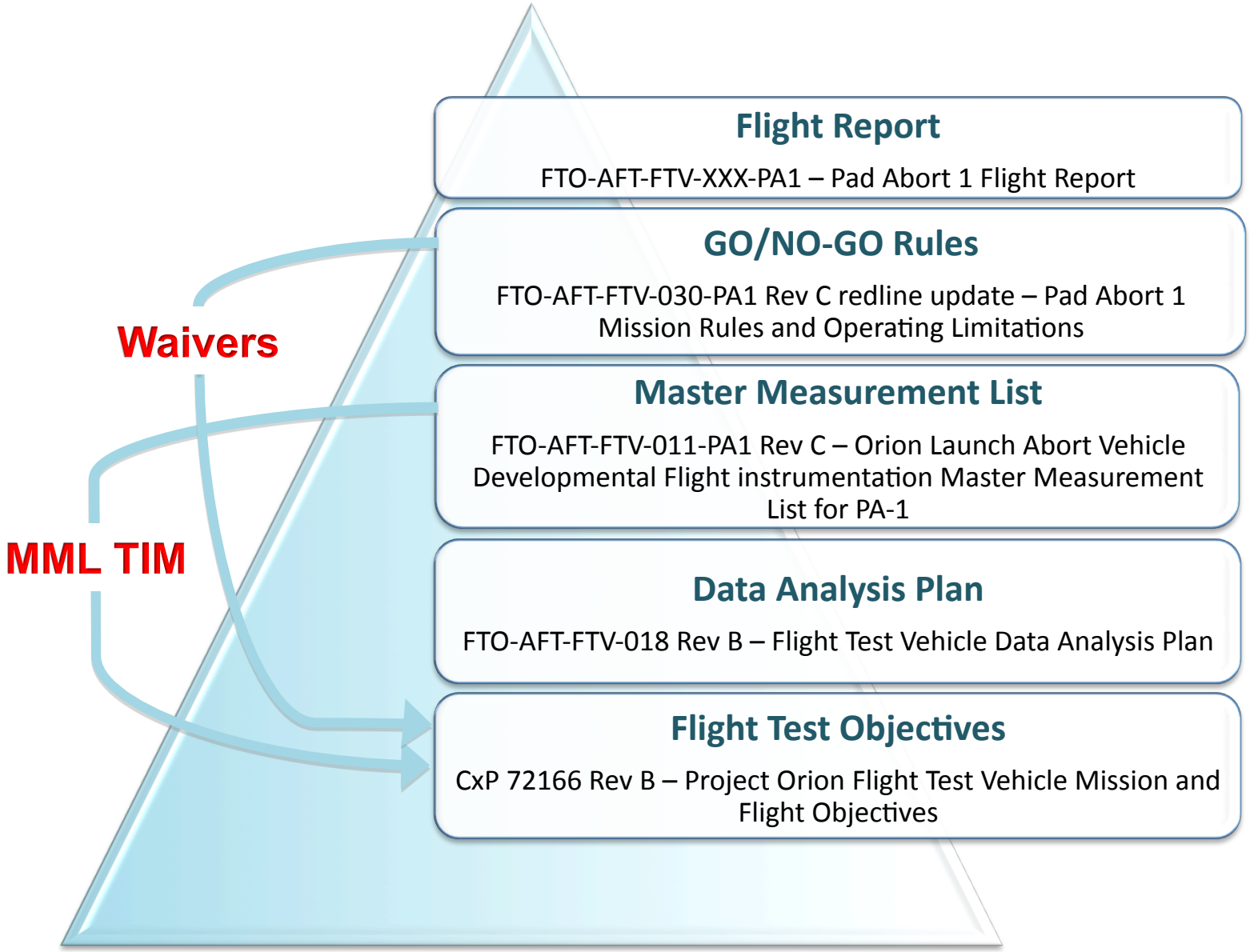
Objective: a thing aimed at or sought; a goal.

Flight Test Objective: an objective that defines all or part of the rationale for undertaking a series of tests or data analyses allocated to a specific flight test.

Agenda

- Flight Test Objective Development Process
- PA-1 Flight Test Objectives
- PA-1 Mission Success Criteria
- A Couple of PA-1 Flight Test Objective Assessments
- Concluding Remarks

Bottom-Up Development Process



What Makes a Flight Test Objective

- Measure of performance (MOP): How do we know when the objective has been met? MOP's are general statements, e.g., LAS range from the launch pad.
- Evaluation criteria: Provides the basis for quantitative evaluation of the MOP. For instance, LAS range from the launch pad greater than 4000 ft. If the CM didn't make 4000 feet, the flight test objective was not achieved.
- Required Parameters: The parameters needed to ascertain whether the MOP met the evaluation criteria. For this simple example, we'll need to know the LAS position from ground-based or on-board measurements.

Types of Flight Test Objectives

Demonstrate – Denotes the occurrence of an action or an event during a test. The accomplishment of an objective of this type requires a qualitative answer. The answer will be derived through the relation of this action or event to some other known information or occurrence. This category of objective implies a minimum of airborne instrumentation or that the information is obtained external to the flight-test vehicle or both.

Determine – Denotes the measurement of performance of any subsystem or component. This category implies a quantitative investigation of overall operation, which includes, generally, instrumentation for measuring basic inputs and outputs of the subsystem. The information obtained should indicate to what extent the subsystem operated as designed. Instrumentation should allow performance deficiencies to be isolated to either the subsystem or to the subsystem inputs.

Obtain Data – Denotes the gathering of engineering information that is to be measured to augment the general knowledge required in the development of the overall flight vehicle. This category may also be used for supplemental investigation such as environmental studies and ground equipment studies. The degree of instrumentation is not implied by this definition.

Allocated as Primary or Secondary

Primary Test Objective – Objective that is considered mandatory for a particular test. These objectives constitute the main purpose for conducting the test. Malfunctions of the test article or launch vehicle systems, ground equipment, or instrumentation that will result in failure to achieve these objectives will be cause to hold or cancel the test until the malfunction has been eliminated. All these objectives, which are tied to Level II requirements, must be achieved for the flight to be a success or, if not achieved, they are reallocated to a subsequent flight.

Secondary Test Objective – Objective that is considered desirable, but not mandatory. Malfunctions resulting in failure to achieve these objectives will be cause to hold or cancel the test as indicated in mission rules. These objectives may be satisfied by either flight tests or other ground-based test opportunities (e.g., drop tests, wind tunnel).

Technical Areas

- Abort Capability (ACxx)
- Dynamic Stability (DSxx)
- Structural Integrity (SIxx)
- Performance (Pxx)
- Separation (Sxx)
- Recovery (Rxx)
- Environment (Exx)
- Support (Suxx)

Abort Capability

Primary Objectives

AC01p. Demonstrate the capability of the LAS to propel the CM to a safe distance from a launch vehicle during a pad abort.

AC03p. Demonstrate ground-initiated abort.

Secondary Objectives

AC02s. Determine critical performance parameters for the LAV during a pad abort.

Dynamic Stability

Primary Objectives

DS02p. Demonstrate stability and control characteristics of the LAV due to the LAS.

DS08p. Obtain data on the CM dynamic response during all parachute system sequences.

Secondary Objectives

DS01s. Determine stability characteristics of the LAV configuration.

DS03s. Determine the reorientation dynamics of the LAV.

DS04s. Determine CM dynamic response to LAS jettison.

Structural Integrity

Primary Objectives

SI03p. Obtain LAS/CM interface structural loads data.

Secondary Objectives

SI02s. Obtain LAS structural loads data.

Performance

Primary Objectives

P01p. Determine the performance of the abort motor.

P02p. Demonstrate the ability of the LAS to jettison from the CM.

P04p. Determine the performance of the ACM.

Secondary Objectives

P03s. Determine separation trajectory of the LAS relative to the CM.

Separation

Primary Objectives

S01p. Demonstrate abort event sequencing from abort initiation through LAS jettison.

S03p. Demonstrate CM/LAS separation mechanism.

S07p. Demonstrate jettison of the forward bay cover.

S09p. Obtain data on ground impact locations for LAV modules and elements.

Secondary Objectives

S08s. Determine separation trajectory of the forward bay cover relative to the CM.

Recovery

Primary Objectives

NONE

Secondary Objectives

R01s. Demonstrate parachute assembly system event sequencing.

R02s. Demonstrate the deployment of the drogue parachute system.

R03s. Obtain data on performance of the drogue system.

R04s. Demonstrate the deployment of the main parachute pilot chute.

R05s. Demonstrate the performance of the main parachute system.

R06s. Obtain data on performance of the main parachute system.

Environment

Primary Objectives

E03p. Determine external acoustics environment before LAS separation.

E05p. Determine external aerodynamic environments before LAS separation.

E16p. Obtain data on ACM plume interaction with LAV before LAS jettison.

E10p. Demonstrate telemetry transmission capabilities of the antenna system (pre-, during, and post-LAS jettison).

Environment (continued)

Secondary Objectives

E01s. Obtain data on abort motor plume interaction between the LAS and the CM or LAS Fairing Assembly (if available).

E02s. Determine LAS/CM interface vibration.

E13s. Obtain data to validate the ascent venting analysis for the vent paths.

E15s. Determine external aerodynamic environments following LAS separation.

E06s. Determine thermal environments during all phases of the test.

E07s. Determine acceleration environments during all phases of the test.

E08s. Determine shock environments during all phases of the test.

E09s. Obtain data on landing load environment.

Support

Primary Objectives

SU01p. Demonstrate functional performance for GSE command control monitoring system.

SU02p. Demonstrate functional performance for GSE transportation handling and covers.

SU04p. Demonstrate functional performance of GSE special tools and test equipment.

Secondary Objectives

SU03s. Demonstrate functional performance for GSE commodity servicing equipment.

PA-1 Success Criteria

Minimally Successful

Abort motor and attitude control motor ignite and LAV (launch abort vehicle) achieves lift off with both motors firing.

Successful

ACM continues firing and controlling as or nearly as expected and controls LAV downrange, conducts a successful reorientation, and delivers the entire LAV to the proper attitude for LAS jettison.

Fully Successful

All above objectives achieved plus deployment of forward bay cover, 2 drogues, 3 pilots and 3 main chutes extract and inflation to first stage.

Two Example Assessments

P03 Determine separation trajectory of the LAS relative to the CM.

S08 Determine separation trajectory of the FBC relative to the CM

Objective Assessment No. 1

P03 Determine separation trajectory of the LAS relative to the CM.

Measures of Performance

- Evaluate the CM attitude relative to LAS
- LAS position and velocity derived from RADAR data
- Evaluate the CM rates relative to LAS
- Evaluate the CM acceleration relative to LAS acceleration
- Evaluate the CM velocity relative to LAS velocity
- Evaluate the CM position relative to LAS position

Evaluation Criteria

- CM and LAS state data will be compared with the FTO 6DOF simulation prediction of CM and LAS trajectories

Required Data

- CM position, velocity, acceleration, attitude, angular rates, airspeed, angle of attack, and sideslip (inertial estimates) derived from on-board instrumentation
- LAS position and velocity derived from RADAR data
- Day-of-flight winds, atmospheric conditions derived from WSMR weather balloon, and LAS-CM displacement measurement

Objective Assessment No. 2

S08 Determine separation trajectory of the FBC relative to the CM

Measures of Performance

- Evaluate the CM attitude
- Evaluate the CM rates
- Evaluate the CM accelerations
- Evaluate the CM position with respect to forward bay cover position
- Evaluate the CM velocity with respect to forward bay cover position

Evaluation Criteria

- CM and FBC state data will be compared with the FTO 6DOF simulation prediction of CM and FBC trajectories

Required Data

- Camera (from CPAS) with paint scheme on forward bay cover, long range video
- CM position, velocity, acceleration, attitude, angular rates, airspeed, angle of attack, and sideslip (inertial estimates) derived from on-board instrumentation
- FBC position and velocity derived from RADAR data
- Day-of-flight winds, atmospheric conditions derived from WSMR weather balloon

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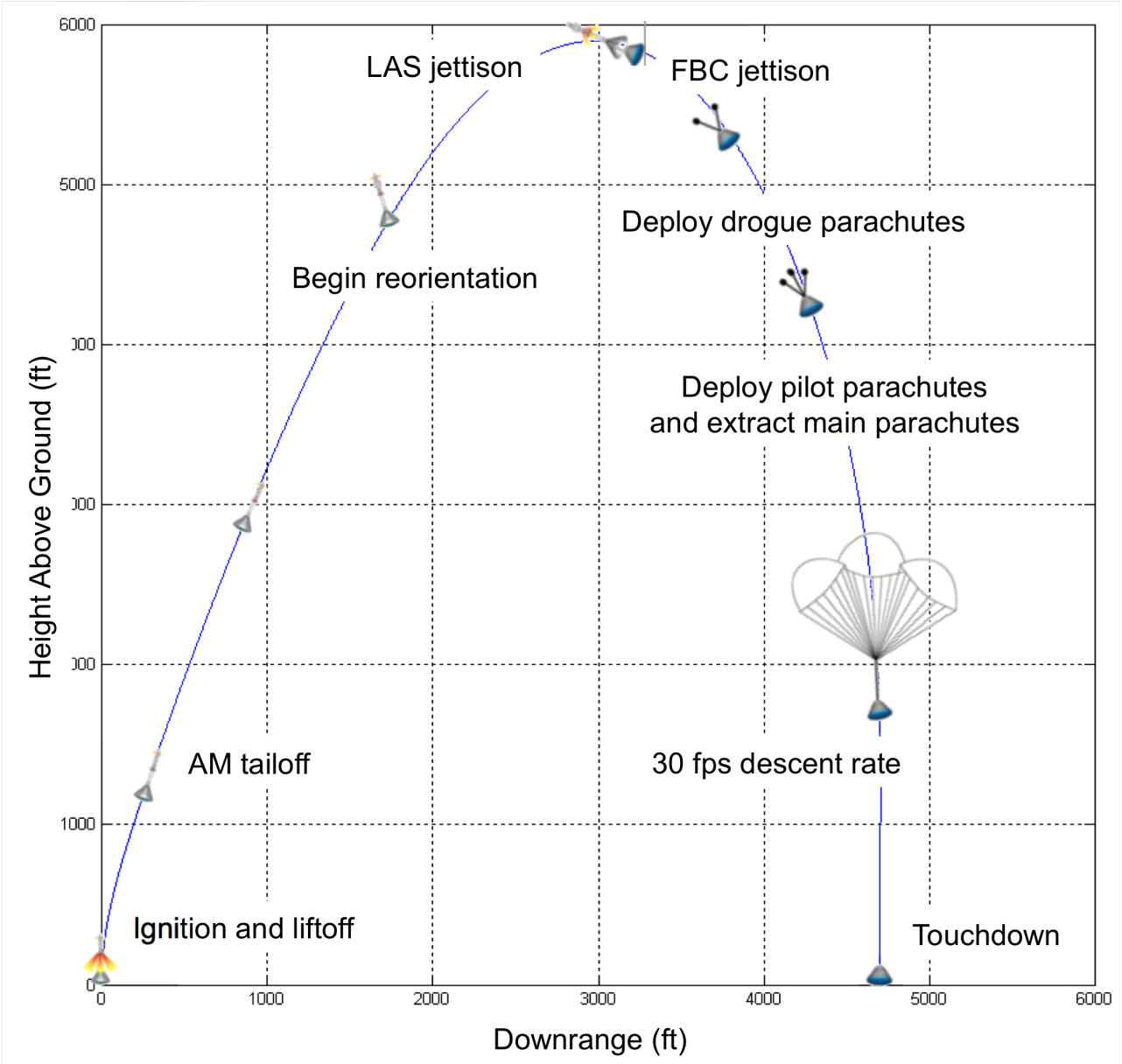
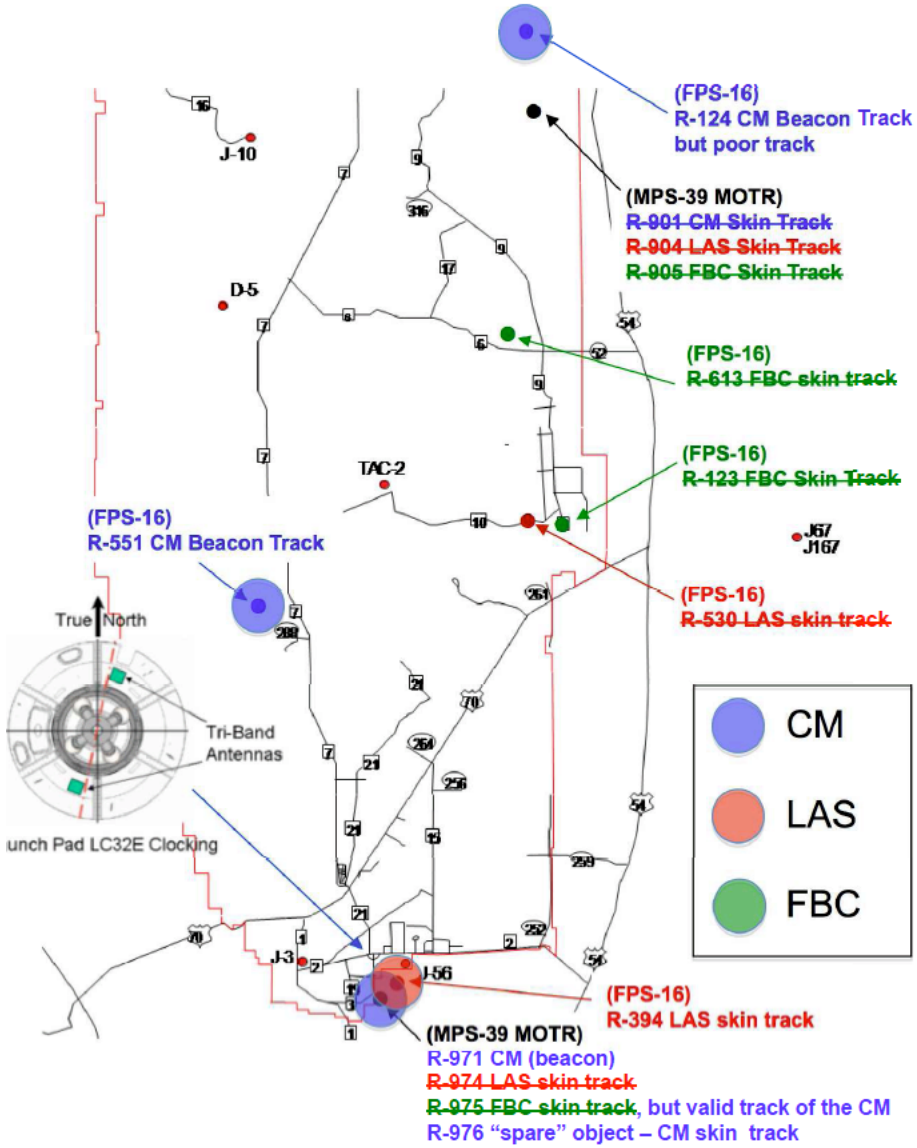
Objective Assessments

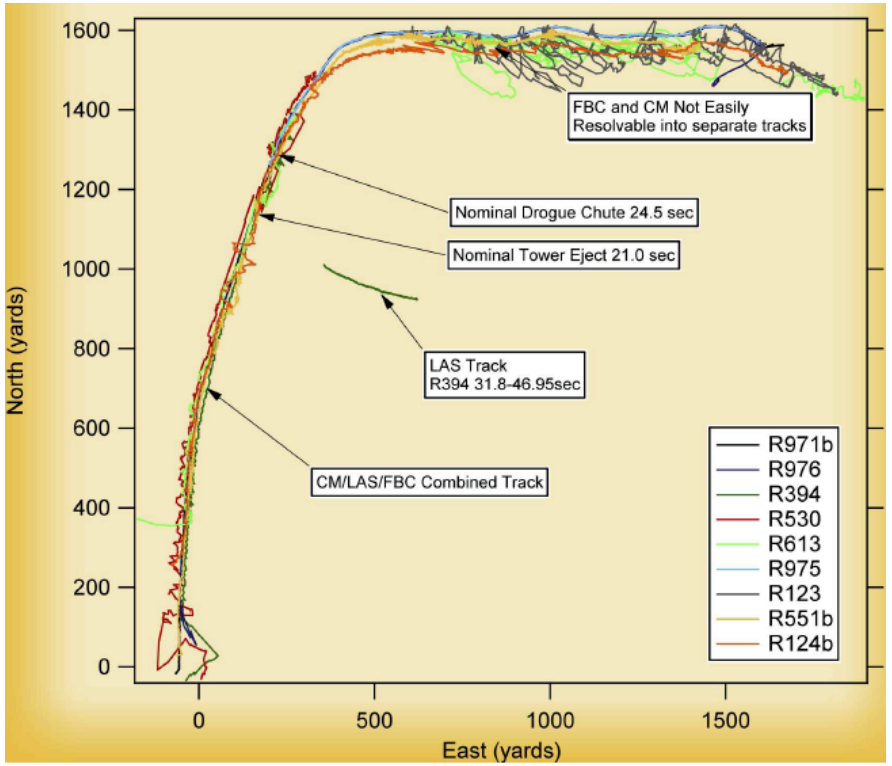
- Radars failed to track LAS or FBC at separation
  - LAS was tracked by one radar, but only only 10 sec. after sep
  - No radars tracked the FBC
- Optical tracking of LAS failed, only 1 of 5 cameras tracked the LAS (the rest stayed with the CM)
- Three ground-based cameras showed CM, FBC, and LAS for approximately 1.5 seconds
  - Assuming co-planar motion, estimates of separation distance vs. time can be made
  - LAS and CM height allowed two estimates from each video file
- CM tunnel film camera also allowed one additional estimate of the FBC separation distance vs. time

PA-1 Planned Abort Trajectory



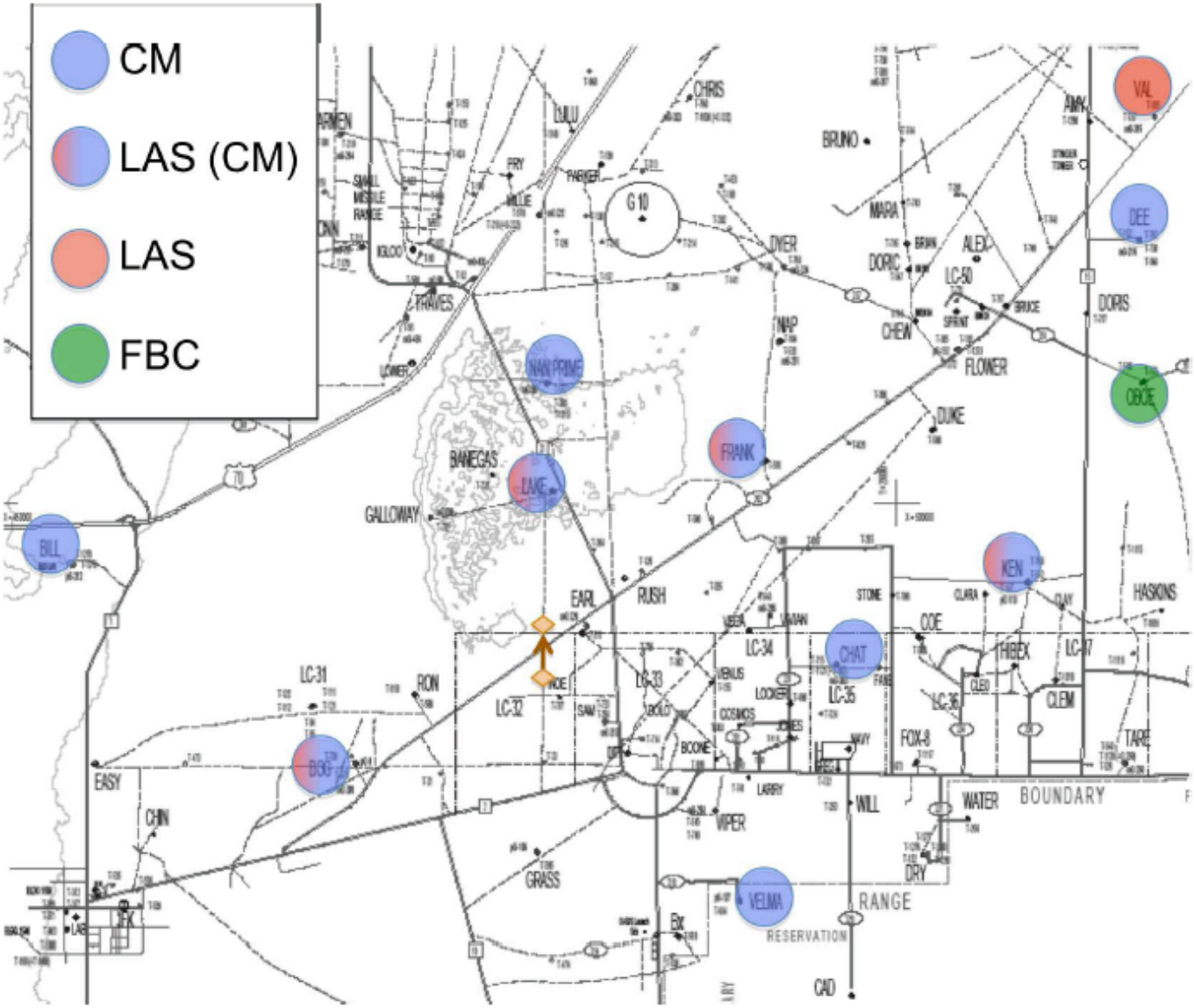
WSMR Radar Used for PA-1



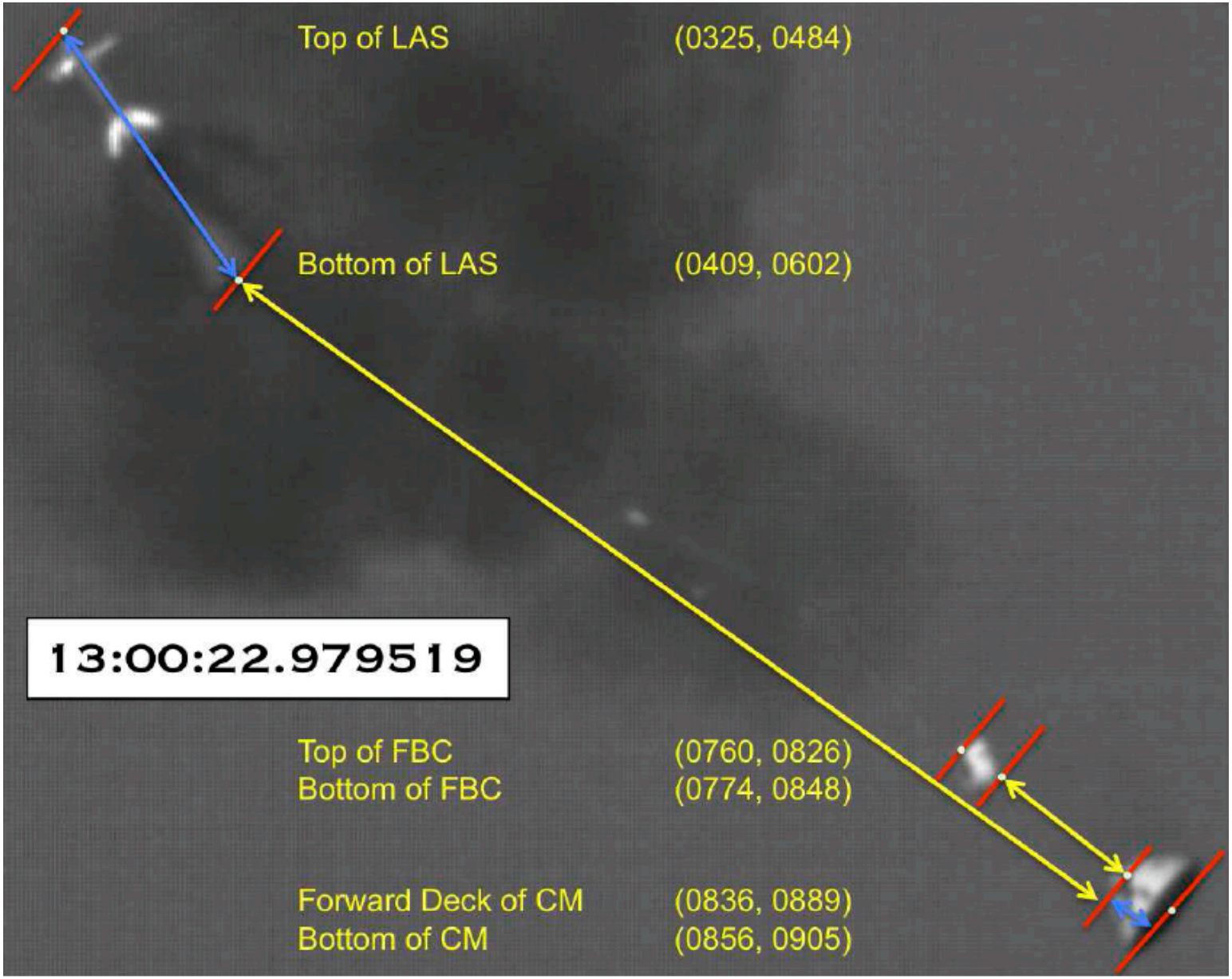


Radar	Type	Site	Assignment	Performance
R971	MOTR	Wise	CM (beacon)	Good track very high quality data
R551	FBS-16	Rad	CM (beacon)	Good track high quality data
R901	MOTR	not named	CM (beacon)	No track
R124	FPS-16	not named	CM (beacon)	Poor track due to low elevation and long range
R976	MOTR	Wise	"spare" object	Good CM skin track
R394	FPS-16	Cad	LAS	Good track on LAS 10 seconds after separation
R530	FPS-16	Adam	LAS	Invalid track
R904	MOTR	not named	LAS	No track
R974	MOTR	Wise	LAS	Invalid track
R123	FPS-16	Malone	FBC	Multi-object noisy track of CM and FBC
R613	FPS-16	not named	FBC	Multi-object noisy track of CM and FBC
R905	MOTR	not named	FBC	No track
R975	MOTR	Wise	FBC	Remained on CM (valid track of CM)

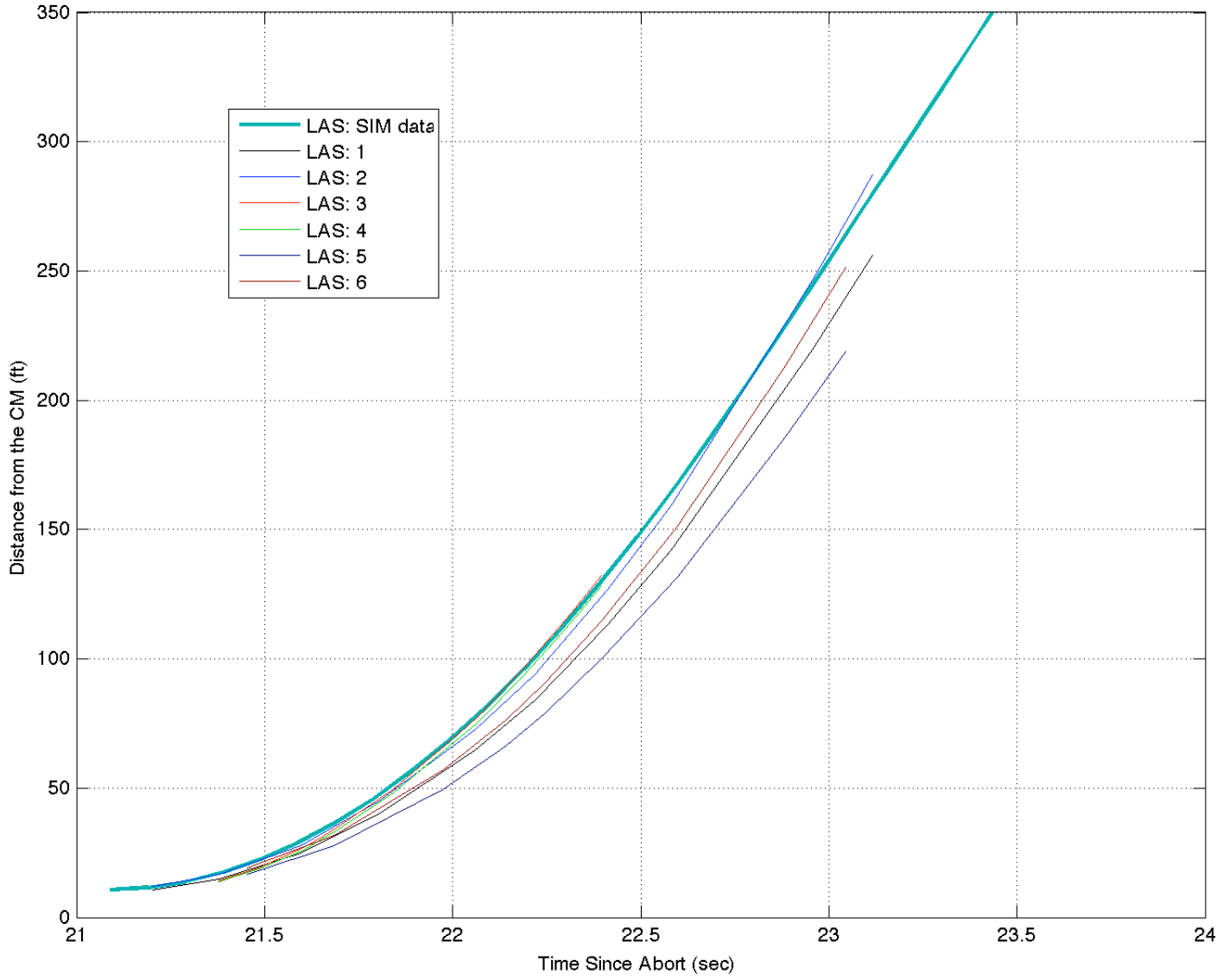
WSMR Tracking Cameras



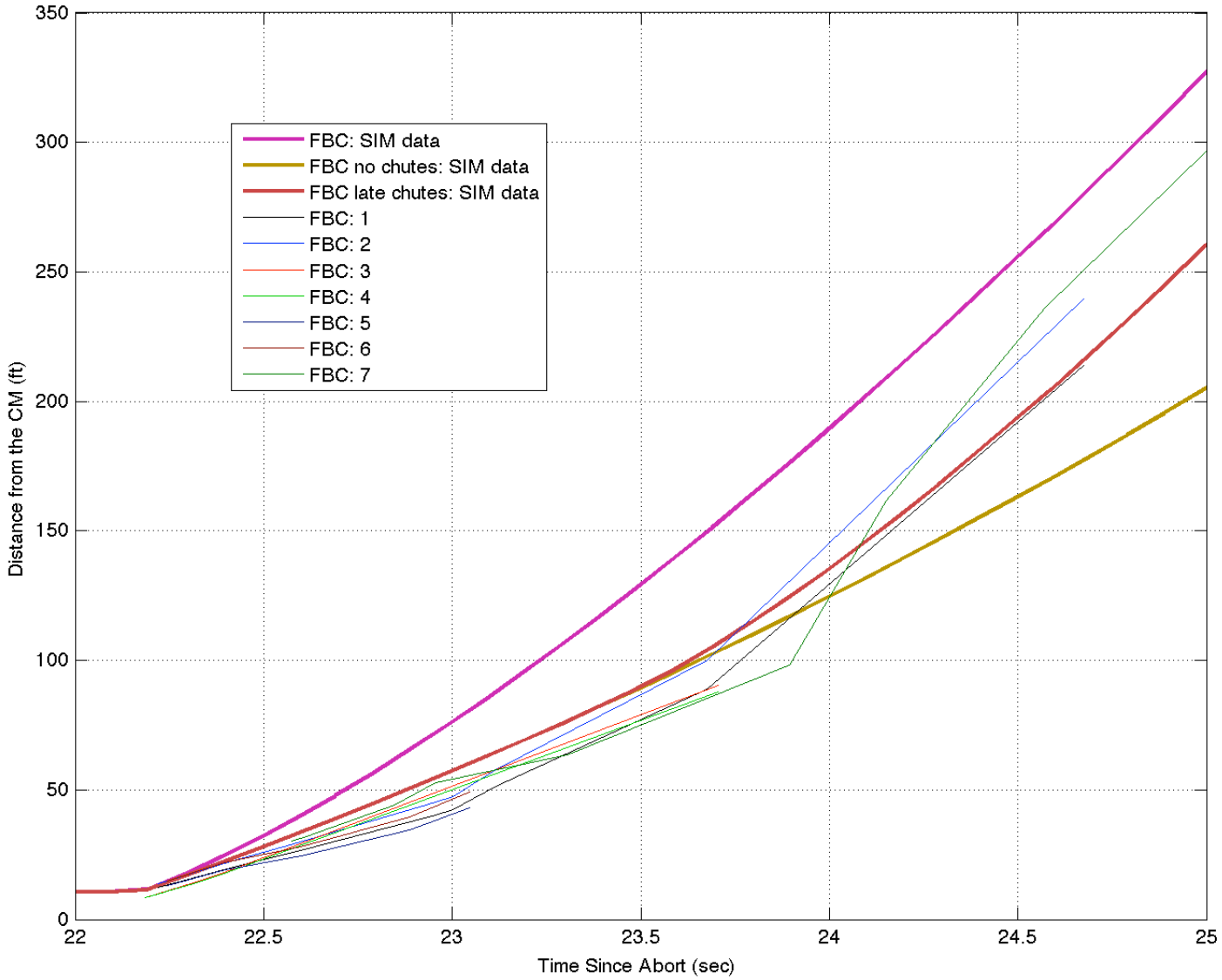
Typical Ground-Based Video



P03 Determine separation trajectory of the LAS relative to the CM.



S08 Determine separation trajectory of the FBC relative to the CM



Concluding Remarks

- The PA-1 test was successful and the flight test objectives were largely met
- The methodology used to develop the flight test objectives, measures of performance, evaluation criteria, and required data allows for a focused effort to drive out the design the instrumentation system
- Sometimes additional and unusual efforts were required to work around problems with the flight data
- Other presentations in the three special PA-1 sessions will present results documenting the successful achievement of many of the PA-1 flight test objectives