

Development Status for the Stennis Space Center LIDAR Product Characterization Range

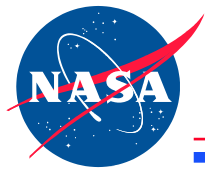
Vicki Zanoni

NASA Earth Science Applications Directorate
Stennis Space Center

Judith Berglund, Kenton Ross

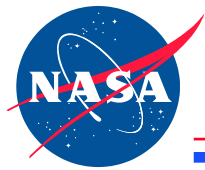
Lockheed Martin Space Operations – Stennis Programs
Stennis Space Center

ASPRS 2004 Annual Conference and Technology Exhibition
Denver, CO, May 23-28, 2004



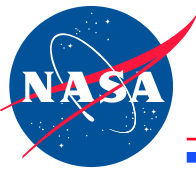
Introduction

- Government agencies, research institutions, and industry are using LIDAR imagery for a range of applications.
- USGS and NASA Stennis Space Center will collaborate to characterize LIDAR data products.
- A number of products are available with limited insight on data characteristics.
- NASA Stennis LIDAR Characterization Approach
 - Utilize in-flight test range to characterize LIDAR data product accuracy
 - Develop LIDAR product characterization range at Stennis
 - LIDAR product characterization is the next phase of the NASA V&V range development.



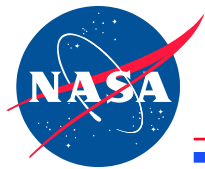
LIDAR Characterization Range Initial Development Approach

- Follow Draft National Digital Elevation Program (NDEP) Guidelines for Digital Elevation Data (2003)
- Characterize vertical and horizontal accuracy
- Primary emphasis, initially, is on vertical accuracy
 - Vertical accuracy of LIDAR products is highly dependent on land cover type



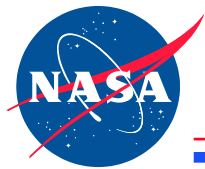
NDEP Guidelines for Digital Elevation Data Accuracy Assessment

- NDEP recommends using a minimum of 20 checkpoints (30 preferred) in each of the ground cover categories representing the area for which digital elevation modeling will be performed.
- The following ground cover categories are identified as the most common:
 - Open terrain
 - Tall weeds and crops
 - Brush lands and low tress
 - Forested areas fully covered by trees
 - Urban areas with dense man-made structures
- NDEP categories not universally applicable
- Ground cover categories should be relevant to the application and study area



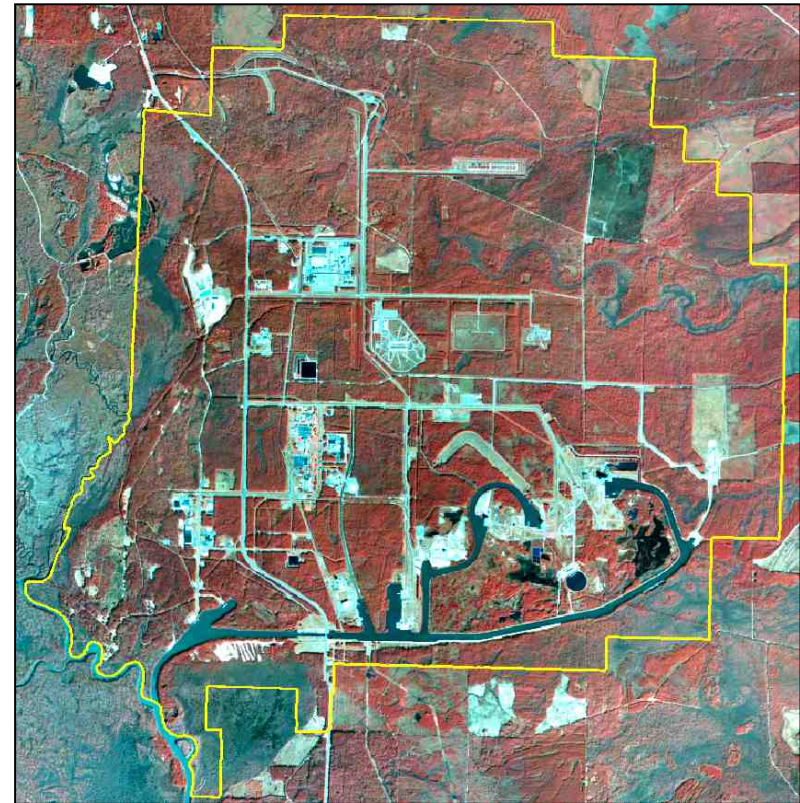
NDEP Vertical Accuracy Definitions

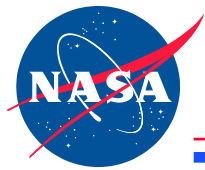
- Fundamental Vertical Accuracy – calculated using only open terrain checkpoints
 - This value can be used to equitably evaluate and compare vertical accuracy among data sets
 - Calculated at the 95 percent confidence level as a function of vertical RMSE
- Supplemental Vertical Accuracy – calculated for other ground cover categories (non open terrain)
 - Calculated non-parametrically as the 95th percentile, since errors will likely not follow a normal distribution
 - 95 percent of the errors have absolute values equal to or less than the accuracy
- Consolidated Vertical Accuracy – utilized when 40 or more checkpoints are combined for 2 or more ground cover types, representing both open terrain and other categories
 - Calculated non-parametrically as the 95th percentile, since errors will likely not follow a normal distribution
 - 95 percent of the errors have absolute values equal to or less than the accuracy



Stennis Characterization Range

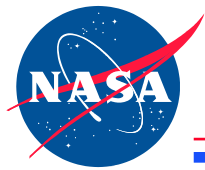
- The Stennis characterization range is built within the Stennis “Fee Area”
 - Approximately 5 mi. x 5 mi. in size
 - Relatively flat terrain
 - ~14 m change in elevation across site
 - Land cover:
 - Buildings
 - Roads
 - Canals
 - Pine Forests
 - Wetlands
 - Open grass
 - Characterization Targets
 - Geodetic network
 - Concrete edge targets
 - Radiometric targets and atmospheric instrumentation





Stennis Space Center LIDAR Range Development

- Stennis LIDAR range development began prior to release of Draft NDEP Guideline
 - Initial range survey planned according to North Carolina Floodplain Mapping Program Issue Paper 37
- Land cover categories selected intended to represent the 5 common categories identified by NDEP
- Some categories were selected, even though they were not extensive within Stennis site



Stennis Land Cover Category A

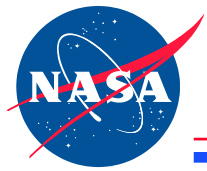
- Bare earth/short grass
 - “short grass” is grass that is regularly mowed
 - all Stennis points are in “short grass” areas

Mixed Lawn Grasses



Exposed Soil at the Landfill

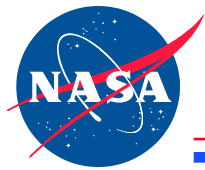




Stennis Land Cover Category B

- High grass/weeds
 - “high grass” may be mowed or burned 1-2 times per year

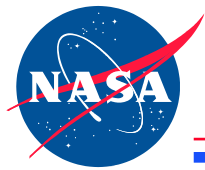




Stennis Land Cover Category C

- Brush / low trees
 - Mostly pine re-growth
 - Uneven canopy allowed, with heights ranging from high grass to up to one or two 4-meter trees within a 5-meter radius from the checkpoint.





Stennis Land Cover Category D

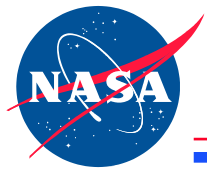
- Fully forested
 - Fairly even canopy, 4 meters or greater in height
 - Mostly pine forest in upper canopy



Slash Pine with Gallberry Understory



**Slash Pine with Regeneration
Hardwood/Brush Understory**

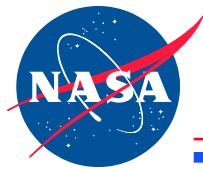


Stennis Land Cover Category E

- Urban
 - Asphalt and concrete surfaces

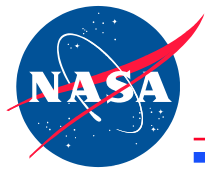


Two Ages of Asphalt



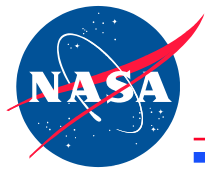
Stennis LIDAR Range Checkpoint Requirements

- Location
 - Each check point separated from nearby obstacles by a distance equivalent to the height of the obstacle plus 5 meters.
 - Allows for $< 45^\circ$ incidence angle plus 5 meters horizontal error.
 - Each check point separated from the boundary between forest and another category by the height of the forest canopy plus 5 meters.
- Terrain Slope
 - In accordance with the NDEP Guidelines (2003), checkpoints were selected in areas of flat or uniformly sloping terrain (slopes 20% or less) for 5 meters in all directions.
 - Flat terrain was preferred to minimize the effect of horizontal error on vertical error estimates.



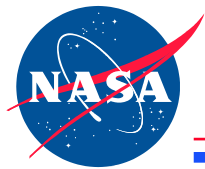
Stennis LIDAR Range Check Point Requirements (cont'd.)

- Number of Points
 - 20 check points in each land cover category, based on NDEP Guidelines (2003), except for high grass/ weeds
 - 31 points were collected for the “high grass/weeds” category to account for the possibility that some of those points may have been recently mown
- Distribution of Points
 - Check points will be well-distributed within each category, especially perpendicular to the direction of flight so that they fall under multiple flight lines. (N.C. Floodplain Mapping Program Issue Paper 37)
 - Within Stennis sties, it will not be possible to meet the more quantitative NDEP Guidelines (2003) suggestions including that at least 20% of checkpoints be in every quadrant of the area of interest and that all points be separated by at least 10% of the diagonal distance across the area of interest.
 - Fully forested category is possible exception

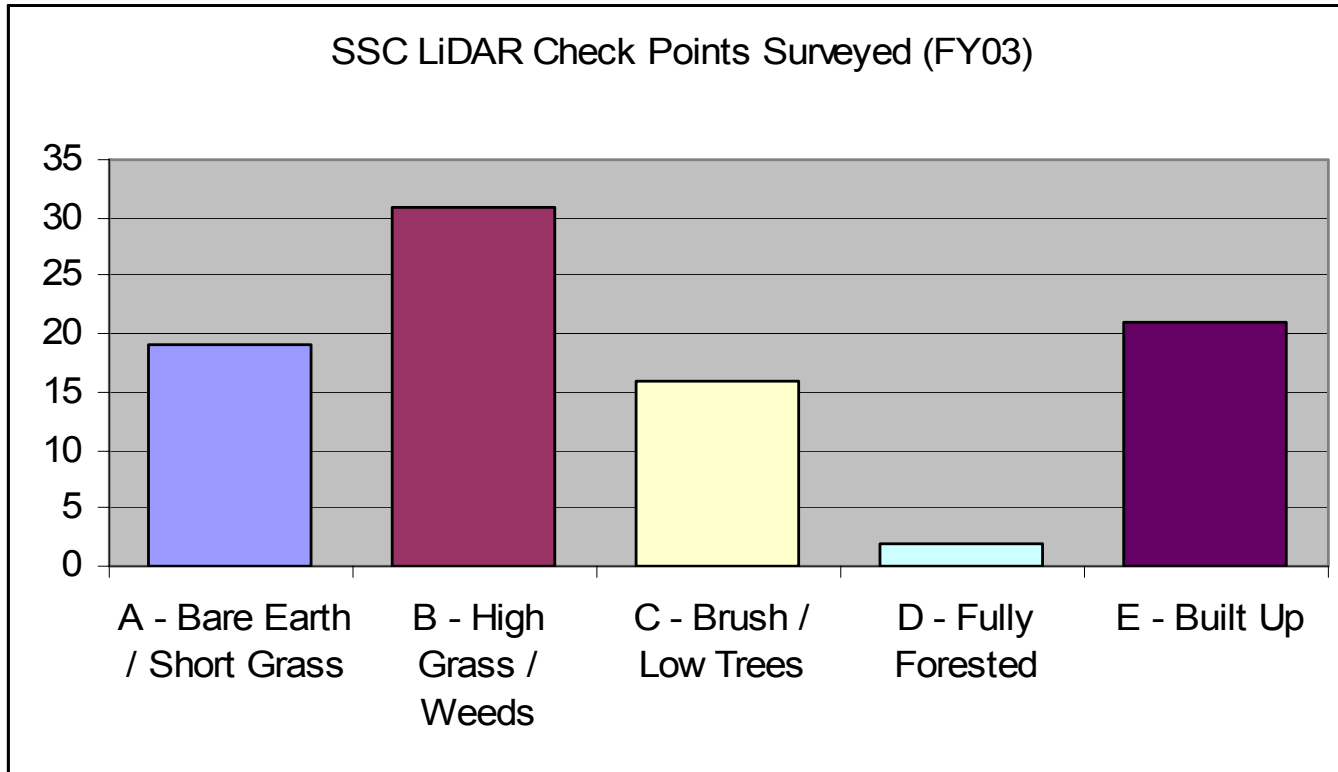


Stennis LIDAR Range Survey Techniques

- All non-forest check points are surveyed with real-time kinematic (RTK) GPS.
 - Each RTK GPS check point is occupied twice according to the procedure laid out in the NDEP Guidelines (2003).
- All forest check points are surveyed with conventional topographic survey by total station.
 - The conventional surveys are being anchored with twice-occupied RTK GPS reference points or A order monuments.
 - Total station survey of the forest check points determines the vertical component by trigonometric leveling.
 - If this does not meet the error budget requirements for a specific LiDAR characterization, the vertical component for forest points could be surveyed later by differential leveling.
 - A follow-on differential leveling effort is not covered in the estimated budget.
- The Accuracy_z (LE95) of check points set to date is 4.2 cm. The Accuracy_r (CE95) for their horizontal error is 1.1 cm.



Survey Status

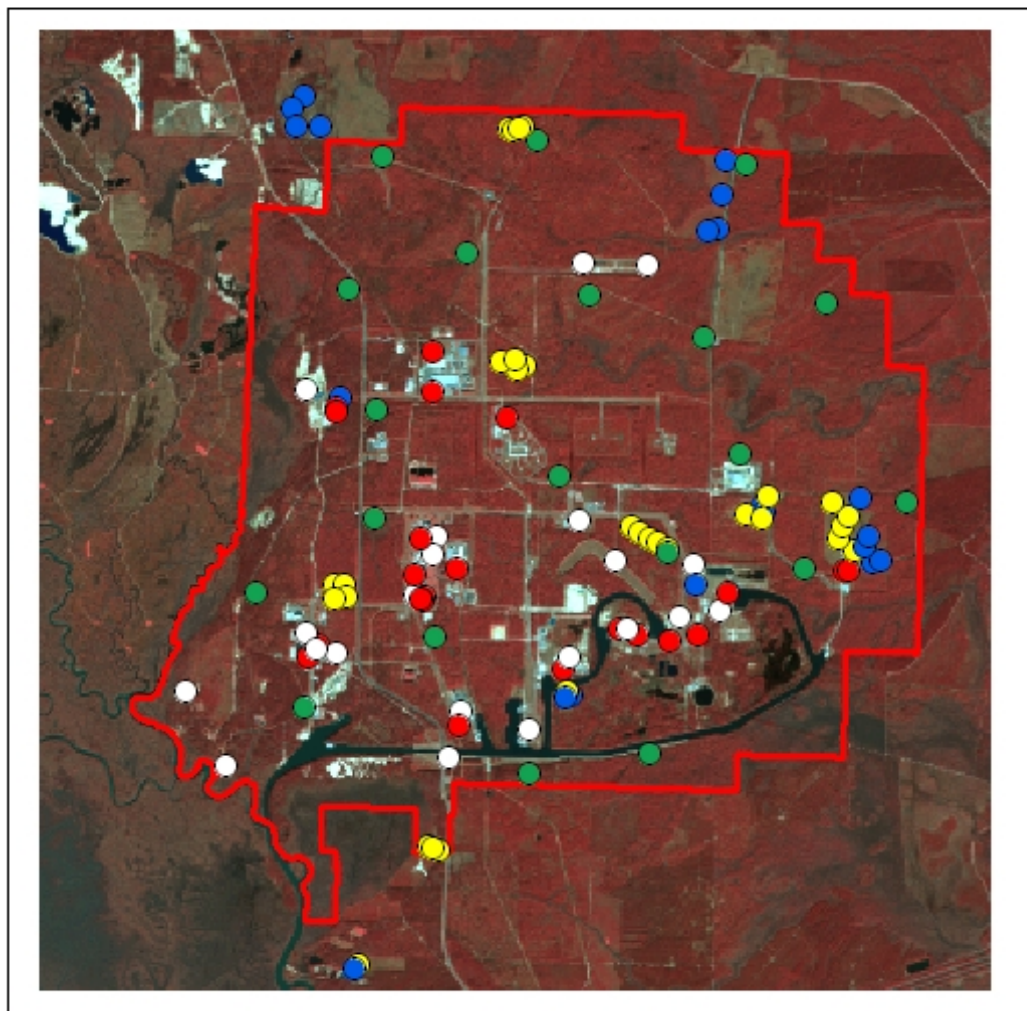


- **Completion of surveying is awaiting additional funding**
- **Goal is to survey a minimum of 20 points in each land cover category**



Stennis Current and Proposed Check Points

SSC Lidar Range Checkpoints

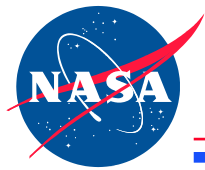


Legend

— SSC Fee Area

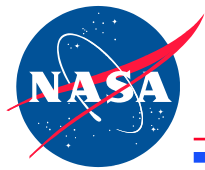
Cover Type

- A - Bare-Earth, Short Grass
- B - High Grass, Weeds
- C - Brush, Low Trees
- D - Fully Forested
- E - Built-Up



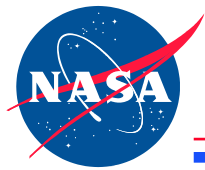
Potential Future LIDAR Data Characterization Range Development

- Methods and targets for characterizing the following aspects of LIDAR data products should be explored:
 - Planimetric (X,Y) accuracy
 - Vertical (Z) accuracy
 - Reflectance dependencies or effects
 - Height discrimination
 - Minimum resolvable height separation for multiple return systems
 - Sampling density
 - Image quality of intensity-based imaging systems
 - Edge response
 - Radiometry
 - Signal-to-noise



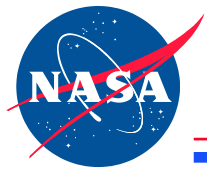
Planimetric/Horizontal Accuracy of Digital Elevation Data

- Horizontal error is more difficult than vertical error to assess in the final elevation product
 - Land surface often lacks distinct topographic features needed (e.g. bare earth DEMs)
 - Need products with visible features that have been GPS-located
- Possible assessment approaches listed by NDEP Guideline (2003)
 - Coordinates of the four corners of rooftops of several buildings are accurately surveyed (in addition to ground control points surrounding these buildings) and compared with LIDAR calibration flights flown over the calibration area from multiple directions.
 - Acquire very high-resolution elevation data where well-defined surface features such as narrow stream junctions, small mounds, or depressions can be identified. Compare surveyed horizontal coordinates with those derived from the high-resolution elevation dataset.
 - Use of intensity data to identify features on the ground and compare their surveyed horizontal coordinates with those derived from the LIDAR intensity images
 - Corresponding intensity data must be earth-referenced by the same process used for the elevation data



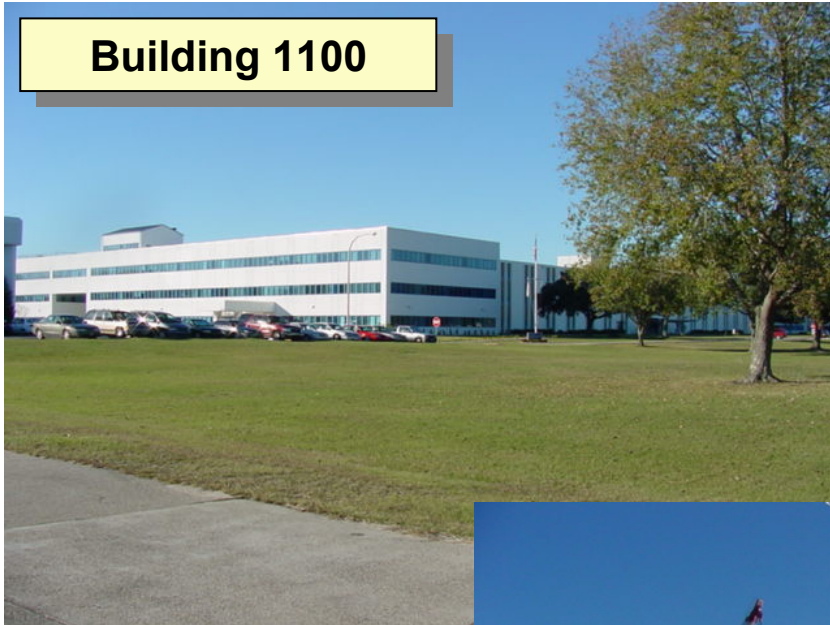
Potential Ideas for Targets to be Developed

- Horizontal Accuracy
 - Building edges
 - Pattern of retroreflectors on ground, on structure, or across water body
 - Dark target with reflectors on edge
- Intensity Imagery
 - Surface model of SSC edge target
- Dependence on pulse footprint size
 - Wire/grid “tree” or trellis structure with substructure (artificial canopy)
 - Sloped wires
 - Netting at angles
- Height Discrimination
 - Box structures of various sizes and heights;
 - Large scale stairs such as stadium seating at a ball field
 - Retroreflectors placed on structures of different heights
 - Pattern of retroreflectors on angled grid



Buildings – Various Heights

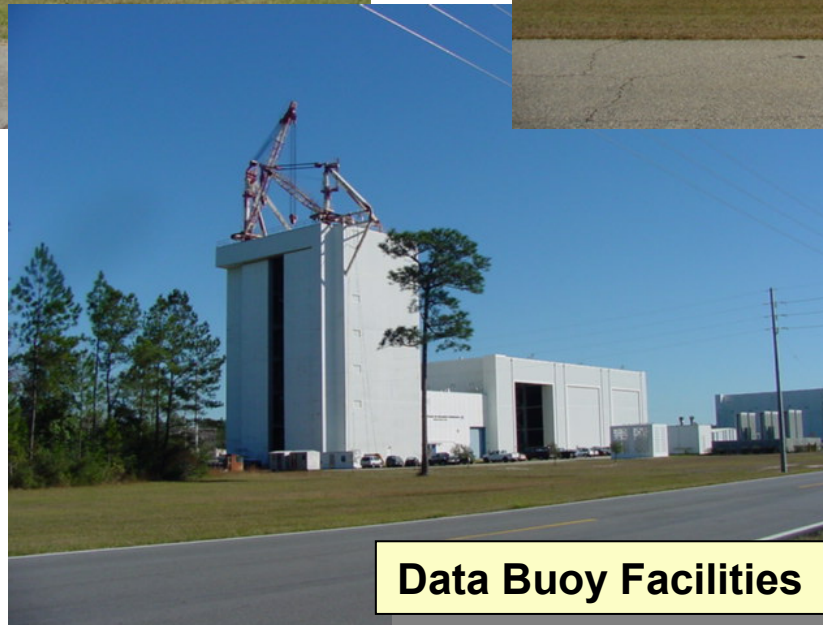
Building 1100

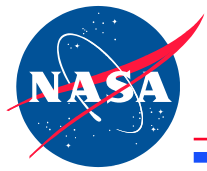


Army Assembly Facility

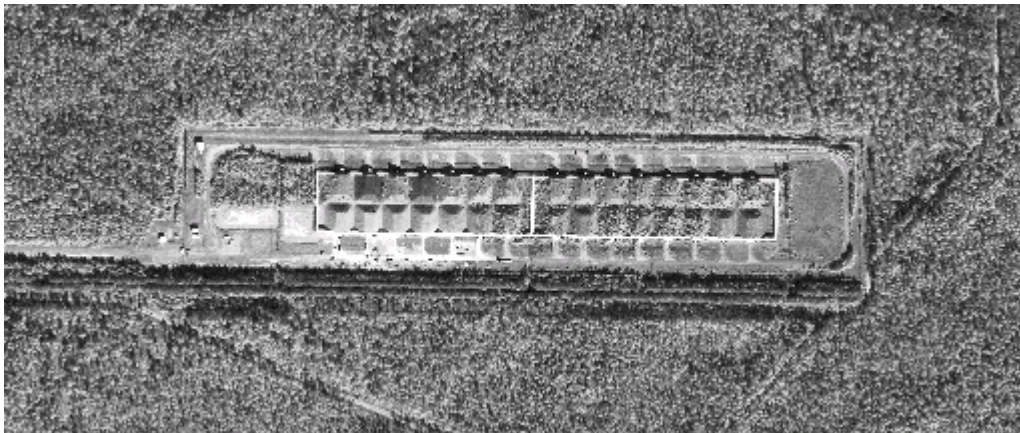


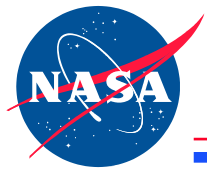
Data Buoy Facilities





Uniform Slopes





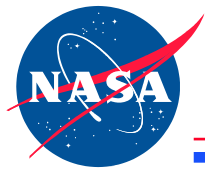
Linear Features



Electric Lines



**Steam Line on the
Army Facility**

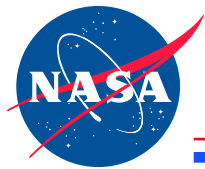


Painted Manhole Covers



- 136 painted/surveyed man-hole covers located throughout SSC fee area
- Paint reflectance nominally 50%
- Manhole cover diameters range between 0.6 and 2.9 meters
- Manhole cover centers have been geolocated by GPS to <3 cm horizontal accuracy and <6 cm vertical accuracy

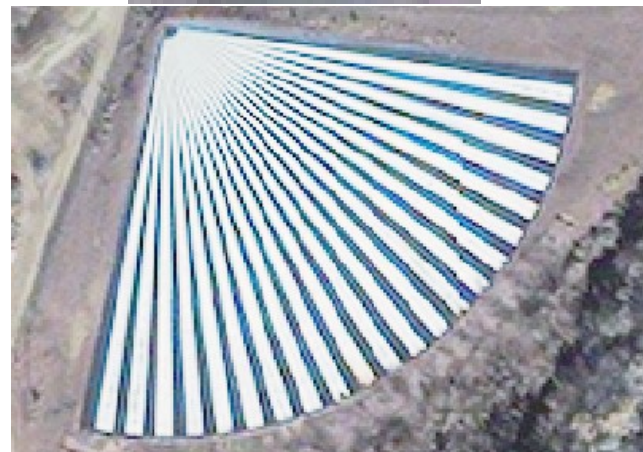
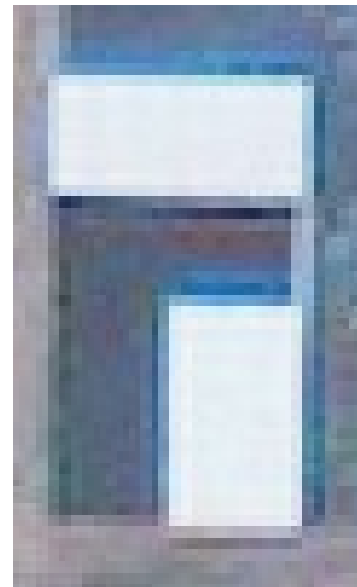




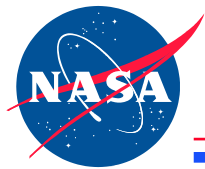
Edge Features



Two Ages of Asphalt



**Edge and Grayscale Target Array,
as imaged by QuickBird**



Short and Tall Grasses, Bare Soil

Native Grasses

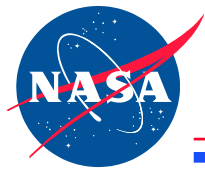


Mixed Lawn Grasses



Exposed Soil at the Landfill





Variety of Forest Cover and Density



Dense Pine Regeneration



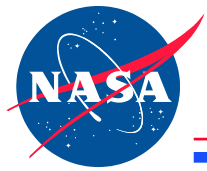
Slash Pine with Gallberry Understory



Slash Pine with Waxmyrtle Understory



**Slash Pine with Regeneration
Hardwood/Brush Understory**



Riparian Areas

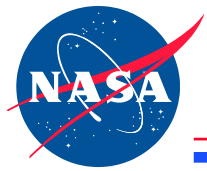


Drain with Mixed Pine Hardwood



Forested Wetland





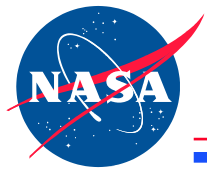
Water Features

Locks on the Canal



Cooling Pond





Interesting Features

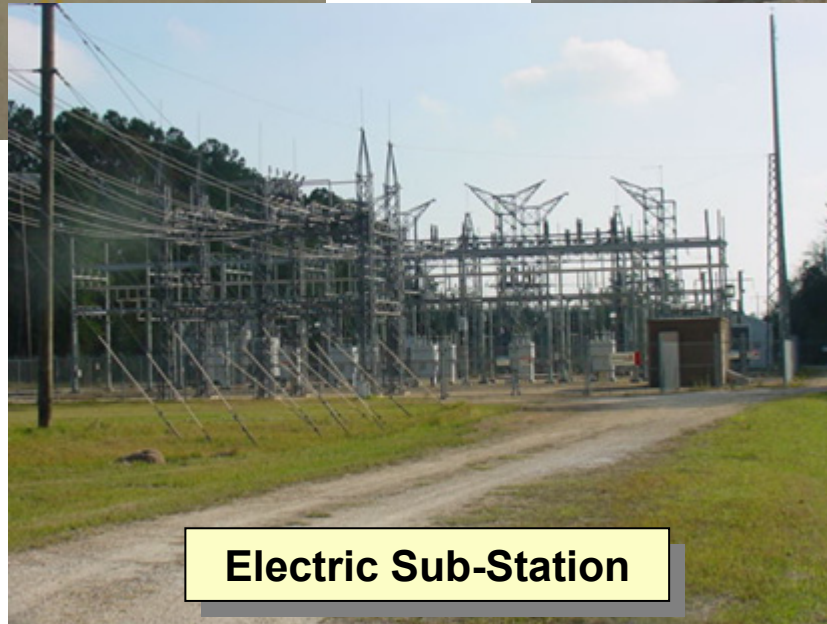
Pipe Structure and Stacks

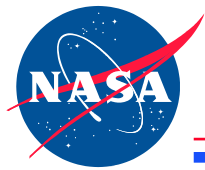


Satellite Dishes



Electric Sub-Station





Interesting Features



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