GROUND TRUTH DATA REQUIREMENTS FOR ALTIMETER PERFORMANCE VERIFICATION

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The amount and type of ground truth required for an altimeter experiment is a function of the uncertainty in the satellite orbit, the altimeter error budget and the type of operation being performed. Ground truth requirements will be discussed with reference to three areas of operation: the global mode, the high intensity mode and calibration.

Figure 1 shows the effects of two different orbital uncertainties on the surface mapping capability of an altimeter whose precision is assumed to be half a meter. One curve is for a tracking network which determines the satellite height to five meters. The other curve shows the effects of a modest tracking network which results in a 100 meter height uncertainty. An interesting thing about the figure is that the high frequency asymptote of both curves is the altimeter precision. The ability to map rapidly varying surface features is independent of the orbital uncertainty and is limited only by the precision of the altimeter.

An altimeter must have a well determined orbit in order to map the general (global) shape of the geoid. But over any short arc the satellite altitude will vary by only a small amount and in a predictable fashion so that the variation of the sea surface can be determined to within the altimeter precision. Even large error in determining the absolute altitude of the satellite is of little consequence when profiling rapid variations in the geoid such as the Puerto Rican Trench.

A typical altimeter error budget for two modes of operation is shown in Table 1. The postulated altimeter has a global mode of operation using a 300 ns pulse width and a high intensity mode using a 25 ns pulse. The only significant noise contributions to the error budget in the global mode are the signal fluctuation and thermal noise residual errors in the instrumentation and the satellite stabilization error. With such a long pulse length the effects of sea state are negligible so that no sea state information is required when operating the altimeter in the global mode. This is the reason for selecting the long pulse length since any intensive ground truth requirement on a global scale would not be possible.

To calibrate the global mode an independent determination of the satellite height above the actual sea surface at some point on the orbit must be made and compared with the altimeter output. Figure 2 shows the quantities of interest at a ground truth site for the calibration of the global mode. The satellite position must be trianglulated and the instantaneous mean sea level (IMSL) of the subsatellite point must be known accurately. The satellite height can be determined to within two meters relative to the tracking stations

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whose heights are referenced to mean sea level. The geoid and any parameters causing MSL to deviate from the geoid and IMSL from MSL will have to be well known for the calibration site. These include the tides, currents and the effects of any storms.

Ideally the calibration site should be where the satellite ground track crosses itself in one orbit. With this redundant point occurring where the satellite position is well defined, any instrumental drift would become apparent because the ground truth site conditions would change by only a small, predictable amount in the period of one orbit.

The purpose of the global mode is to map the general shape of the geoid to five meter accuracy. Due to the long pulse width, the foot print size and precision, this mode would not be suitable for detailed mapping of the rapidly varying portions of the geoid. The global mode would only fix their location on the geoid and indicate their general shape. The high intensity mode would be used to profile the rapid variations.

In the high intensity mode the propagation dependent errors and the ocean scattering effects become significant. Extensive ground truth data must be gathered in support of this mode to evaluate design parameters for refining future altimeters. Table 2 outlines the Wallops Island Ground Truth Program. There are sufficient ground radars in the area (Wallops Island, Bermuda, Florida) to provide excellent orbital parameters.

The ground truth program is built around the Wallops C-54 aircraft, the NASA Wallops Island ship Range Recoverer, and the Chesapeake Light Tower approximately 15 miles east of Virginia Beach. The goal is to obtain sufficient information to remove the sea-electromagnetic bias error, to test models of the effects of the various sea state and atmospheric parameters on the satellite altimeter and elaborate the fundamental limitations of the altimeter. The instrumentation consists of wave staffs, a laser profilometer, two X-band nanosecond radars, a K-band radiometer and photographic equipment for Stilwell photography. The C-54 is instrumented for recording pitch, roll and vertical motion. The instrumentation will provide profiles of the sea surface as well as rms wave height, ocean surface height and slope directional spectra, surface wind speed and direction, air and water temperature and meteorological conditions.

In addition, Wallops has the capability of measuring atmospherics and rain drop sizes so that these contributions in the error budget could be better defined.

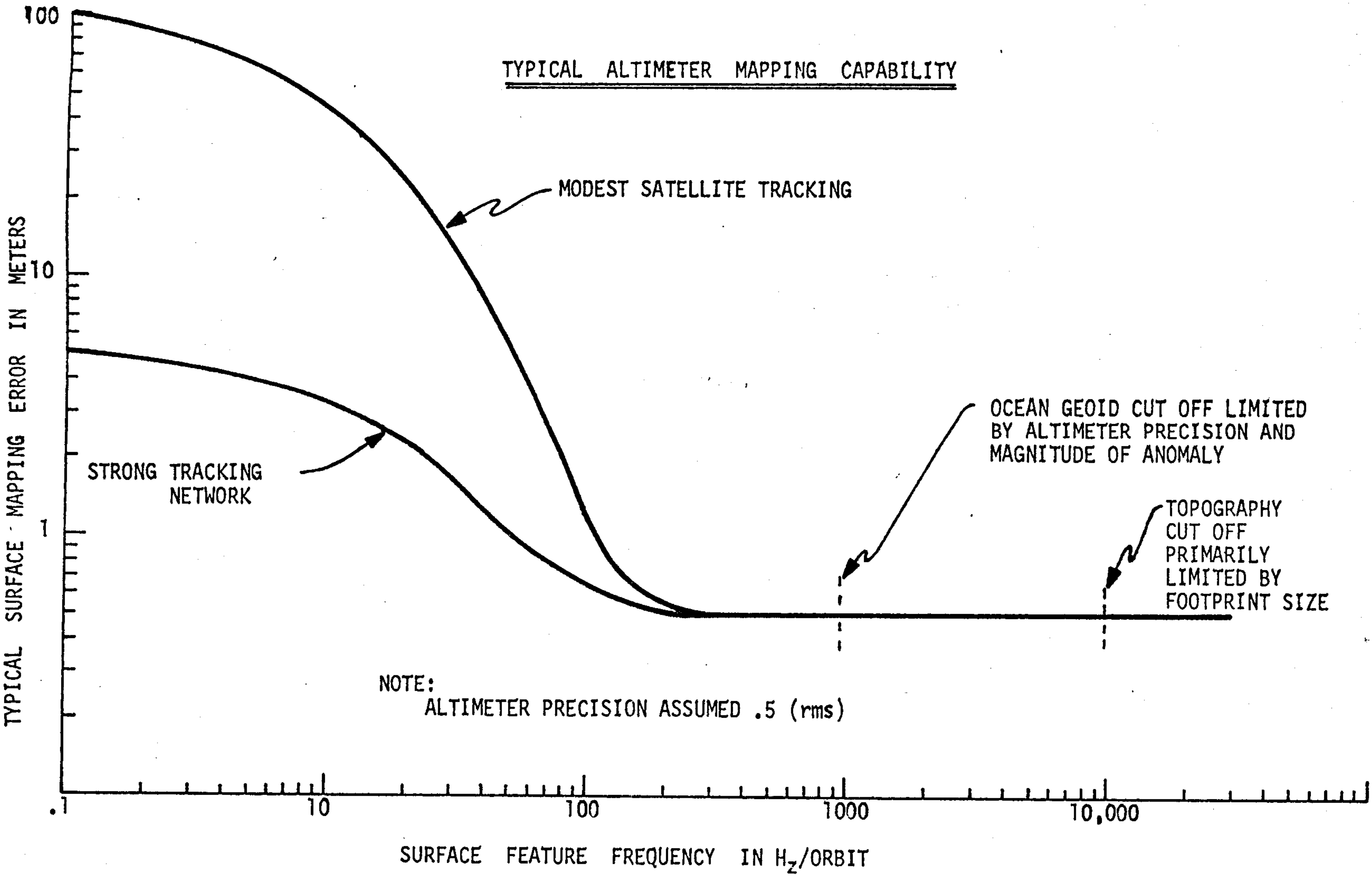
TYPICAL ALTIMETER MAPPING CAPABILITY
MODEST SATELLITE TRACKING
STRONG TRACKING NETWORK
OCEAN GEOID CUT OFF LIMITED BY ALTIMETER PRECISION AND MAGNITUDE OF ANOMALY
TOPOGRAPHY CUT OFF PRIMARILY LIMITED BY FOOTPRINT SIZE
NOTE: ALTIMETER PRECISION ASSUMED .5 (rms)
100
10
1
TYPICAL SURFACE · MAPPING ERROR IN METERS
.1
10
100
1000
10,000
SURFACE FEATURE FREQUENCY IN H_z/ORBIT

Figure 1

TABLE 1

Typical Altimeter Error Budget

	25 ns	300ns
Instrumentation Errors		
Signal Fluctuation and thermal noise residual errors	.30 meters	2 meters
System time delay uncertainty	.06	.15
Range tracker and/or signal processor errors due to nonlinearity	.12	.12
Tracker granularity and clock uncertainty	.10	.10
Propagation Dependent Errors		
Corrected data	.10	.10
Ocean Scattering Effects		
Residual stabilization errors (assuming ±1° uncertainty)	<.1	1 m
Leading edge linearity assumption (~60 cm uncorrected)	.06	.06
Electromagnetic msl bias	.15	.05
	0.4	2.25
Total System Errors (rms)		
for: 5 meter orbit uncertainty	5.02	5.5 meters
1 meter orbit uncertainty	1.08	2.5
.2 meter orbit uncertainty	.47	2.25

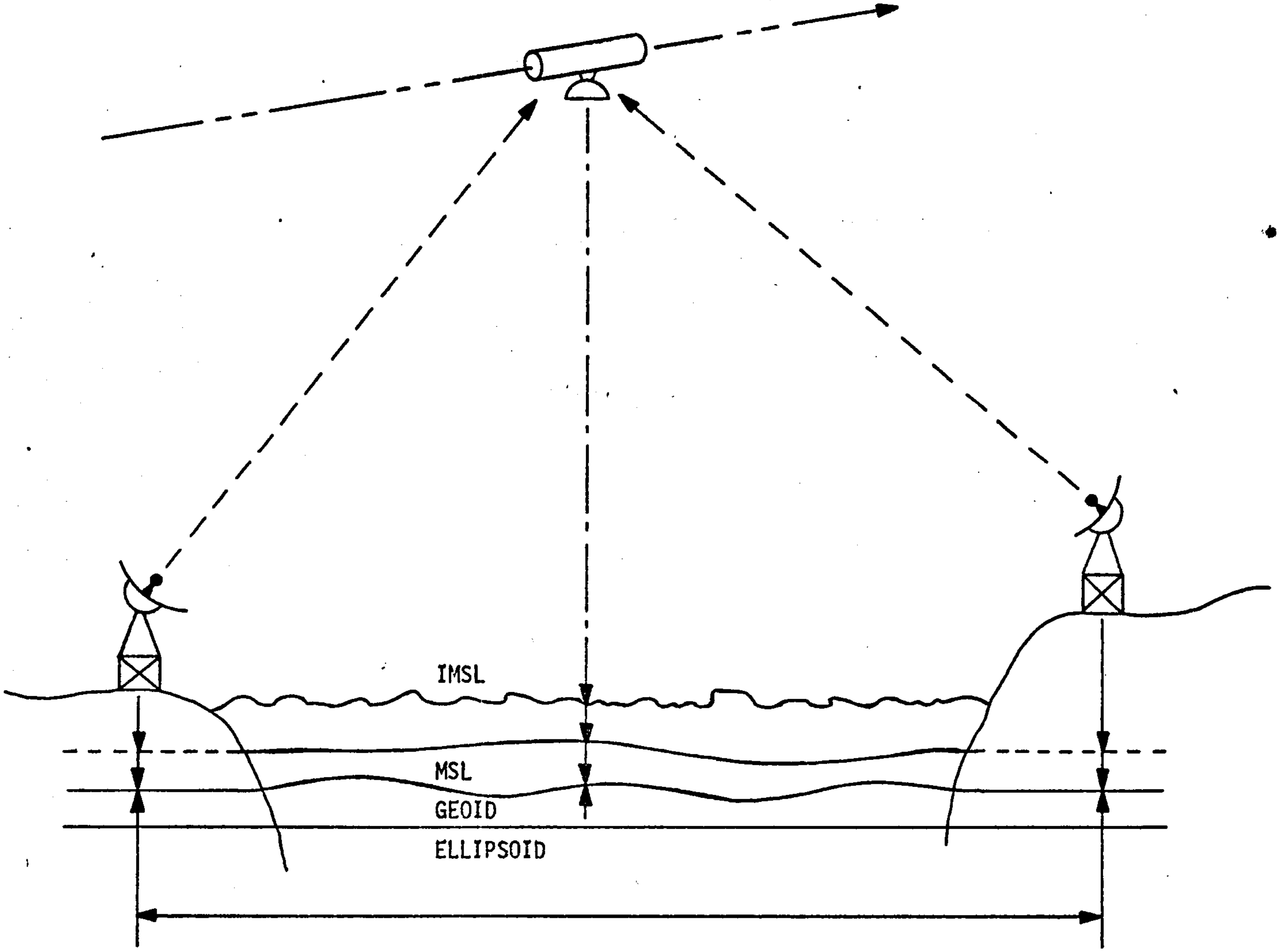

Figure 2

Table 2

Ground Truth System Development Program

1. Instrumented Aircraft and Test Bed

Instrumentation	In-house	External Activity
(a) Stilwell Camera	Lacheman	Katz
(b) Optical Processor	Lacheman	Katz
(c) Nano-second Radar	Selser	Yaplee
(d) Laser Profilometer	Townsend	Peliguin
(e) K-band Radiometer	Novack	Holinger

2. Instrumented Ocean-Tower and Test Bed

Instrumentation	In-house	External Activity
(a) Wavestaff (3 ea.)	Hines	Hammond
(b) Nano-second Radar	Selser	Yaplee
(c) Meteorological Equipment	Spurling	-
(d) Laser Profilometer		

3. Supporting Data Collection System
   - (a) ERTS Photographic Data
   - (b) Commercial Shipping Reports
   - (c) Nembus Photographic Data

Table 2.Continued

(d) Local Meteorological Data

(e) Ground Sites Selection and Evaluation

(f) USNS Range Recoverer for in situ Measurement Data Collection

Ground Truth and Test Bed Activities

1. Ground Truth
    - (a) Chesapeake Ecological Test Site Support
    - (b) SKYLAB Support
    - (c) AAFE Support
2. Test Bed Activities
    - (a) SKYLAB Support
    - (b) AAFE Support
    - (c) Local SR&T Experiments
    - (d) Prototype Altimeter Testing
    - (e) Support to Others