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Technical Report

CURRENT SYSTEMS DEFICIENCIES REPORT

Identified Deficiencies Between USAKA Instrumentation Capabilities and User Needs (a report as part of USAKA Long Range Planning Study)

R.E. SAMPSON
J.C. NELANDER

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ERIM P.O. Box 8618
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This report describes the existing measurement capability at the United States Army Kwajalein Atoll. This is compared with reported current and projected user needs and shortfalls determined. This is part of a series of reports aimed at developing a long range plan for the sensors at Kwajalein.

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1.0 INTRODUCTION

1.1 OBJECTIVE

This report summarizes USAKA user needs and current USAKA instrumentation capabilities in order to arrive at a definition of shortfalls in those capabilities. Both current and near term as well as future (10-15 years) user needs were sought. In order to arrive at this shortfall definition, considerable simplification has been necessary in order to focus on the major measurement and sensor capability areas which should be addressed. USAKA range instrumentation is the focal area of this report including existing and needed radar, optical (visible), infrared, ultraviolet and scoring sensors for metric as well as signature purposes. Direct support capabilities to these sensor functions including meteorological, telemetry and data processing instrumentation and equipment have also been considered. Issues and capabilities relating to indirect support functions such as personnel, transportation, and logistics are not addressed because they do not lend themselves to a direct user need/capability comparison. It may be necessary to address these issues in subsequent efforts directed at resolving instrumentation shortfalls identified by this report.

1.2 APPROACH

The approach used in this study involved four basic steps: (1) acquisition of user needs through direct interaction with USAKA range users; (2) description of USAKA instrumentation capabilities from information gathered via site visits, discussions with USAKA support contractors and review of instrumentation documentation; (3) development and use of common terms and formats for representing user needs and instrumentation capabilities; and (4) request for and use of specific quantitative information for the expression of needs and capabilities. The goal of our approach has been to determine user needs and range sensor requirements in quantitative/measurable terms that define both what measurement capability is needed and the frequency and number of measurements that are necessary. This approach accounted for user needs currently satisfied by existing range capabilities, and also provided the definition, in quantitative terms, of the requirements for capabilities which do not presently exist at USAKA.

1.3 ACTIVITIES

Acquisition of user needs was accomplished by a series of user meetings conducted from December 1988 through March 1989. Visidyne Corporation, under contract to ERIM, collected and categorized user needs. ERIM provided Visidyne with guidelines concerning information required for each instrumentation sensor type. Follow-up questions requesting specific information from users were distributed after most of these conclaves. Details of the user needs assembled in this manner by Visidyne are contained in a separate report.(Reference 1) A distillation of the user data used to develop that report is included in this report to provide a summary of user needs for the identification of capability shortfalls.

ERIM independently conducted discussions with management and staff members from Lincoln Labs and elsewhere to address future technology driven user needs. These needs represent a category of capabilities which are expected to arise during the next ten to fifteen years as a consequence of technology trends (such as stealth) rather than immediate or near term needs as perceived by ongoing user programs.

Activities in support of defining current USAKA instrumentation capabilities included a week long visit to the USAKA Kwajalein Atoll facilities by a team of ERIM representatives in late January 1989. Other facility visits included discussions with Aeromet in Tulsa, Oklahoma, Pan Am World Services in Huntsville, Alabama; the Data Reduction Facility in Honolulu, Hawaii, and several visits to Lincoln

Laboratories in Boston, Massachusetts. Briefing materials and documentation on USAKA instrumentation and capabilities were acquired from each visit. The bulk of this documentation focussed on the radar capabilities at USAKA. Cross checking of this radar material indicated that those reference documents which were more than two years old were generally suspect in their details because of the continuous upgrade of existing capabilities. Only recent reports and information were used as references for this compilation (References 3 and 4).

A special effort was made to formulate statements of user needs in terms of output data parameters and descriptors of user experiment conditions rather than instrumentation engineering capabilities. Frequently, the latter were specified by users based on their experience in using sensors to satisfy their information needs. We attempted to clarify such user need statements in terms of what information was needed rather than how it was to be acquired. It was our belief that this would permit a clearer picture of all user needs, and would further enhance USAKA's ability to predict and satisfy a broader range of user measurement requirements for the future. The results of this effort are contained in a separate report (Reference 2).

The goal of quantifying user needs in measurable terms was accomplished. However, in a variety of cases, the information gathered had minor inconsistencies. These inconsistencies were most notable in the cases of user radar needs and arose either because of mis-communications with users or because users were unaware that some requirements were not totally independent in terms of the engineering parameters of the radars. Similar disparities occurred between different documentation references on the same instrumentation radars. In both the case of user needs and instrumentation capabilities, judgments were made in order to represent parameter values by a single number or set of values in order to permit a comparison of user requirements and capabilities.

1.4 REPORT CONTENT AND ORGANIZATION

The remainder of this report is organized into sections on User Data Needs (Section 2.0), USAKA Capabilities (Section 3.0), Identified Shortfalls (Section 4.0) and General Comments and Conclusions (Section 5.0). Since user data needs are presented in Reference 2 in detail, Section 2.0 is composed primarily of tabular data which summarizes user needs. Section 3.0 contains a more lengthy narrative of USAKA capabilities. It is concluded by tabular data, in the same general format as that used in Section 2.0, that represent a quantitative summary of USAKA instrumentation capabilities. Section 4.0 identifies significant deficiencies which became apparent by comparing Sections 2.0 and 3.0.

2.0 USER NEEDS

2.1 GENERAL

User needs are summarized according to five basic categories: radar; passive RF; optical; environmental and telemetry. Within the active radar category there are seven different frequency bands represented (VHF, UHF, L, S, C, X and Ka), each in a separate table. Passive radio frequency (RF) needs are shown by a single table. Optical data needs are subdivided into five subcategories (UV, visible, SWIR and MWIR, LWIR and LLWIR), each with a separate table. Environmental and telemetry data needs are each represented by a single table.

2.2 RADAR DATA NEEDS

Radar requirements are summarized in Table 2-1 through 2-7. Each of these tables specifies the frequency band designator and the numerical value for the center frequency. The format for each frequency band is the same and consists of seven topic areas: (1) functions (metric and tracking); (2) output data (quality, quantity and type); (3) tracking accuracy (biases, precision and PRF rate); (4) radar/target geometry designators (principally the maximum range); (5) target complex descriptors (number of simultaneous targets, the volume they occupy and the minimum separation between targets); (6) imaging needs (resolution); and (7) other factors or comments.

Where available quantitative entries have been made for each parameter using the most stringent requirement from the total user database. In most cases, entries are labelled in accordance with a user symbol shown at the top of each table. In cases where multiple entries may assist in clarifying user needs, these have been made. When no specific quantitative requirement has been defined by any

TABLE 2-1

RADAR USER NEEDS

CENTER FREQUENCY VHF

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC
(F) NASA
(G) DNA
(H) USAF/SSD

FUNCTIONS
METRIC X SIGNATURE X OTHER ______

OUTPUT DATA
MAX. BANDWIDTH 7.05 MHz (A-H)
PULSE LENGTHS .25, 6, 30, 238 μsec (A-E; H)
POLARIZATION Not Specified
RCS ACCURACY 1 dB (A-E; H)
MIN. SNR @ 1000 KM. RANGE, 0dBsm TGT 31 dB (A-C; E, H)
VECTOR UPDATE RATE 20 Hz (C)
PRF 10-2976 (D; A-E, H)

TRACKING ACCURACY
RANGE BIAS 1.5 m (C-E; H)
ANGLE BIAS 250 μrad. (A-E; H)
RANGE PRECISION +/-0.5 m (C,D)
ANGLE PRECISION +/-90 μrad. (A, C-E, H)
BEACON TRACK No (A-H)

MISS DISTANCE: YES (A,C)

RADAR/TARGET GEOMETRY
MAX. RANGE 4000 km (A-C, E, H); 19,000 km desired by (D); 37,000 km (G)
MIN. RANGE 15 km (A-C)
MAX. ELEV. ANGLE 90° (D, F-H)
MIN. ELEV. ANGLE Horizon (A-C)

TARGET COMPLEX
MAX. NO. OF TARGETS 16 (C)
MIN. RCS -25 dBsm (C,D)
MAX. COMPLEX DIMENSIONS: RANGE 300 km (A-C) ANGLE. 3° (A-C)
MIN. TARGET SEPARATION: RANGE 100 m (D) ANGLE. 0.15° (A-B)
MANEUVERING TARGET (ACCEL.) yes (A)(C)(H)

IMAGING YES ____ NO (X)
RANGE RESOLUTION N/A
AZIMUTH RESOLUTION N/A

OTHER
Simultaneous collection at VHF and UHF (G)

TABLE 2-2

RADAR USER NEEDS

CENTER FREQUENCY UHF

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC
(F) NASA
(G) DNA
(H) USAF/SSD

FUNCTIONS
METRIC X SIGNATURE X OTHER ____

OUTPUT DATA
MAX. BANDWIDTH 18 MHz (A)
PULSE LENGTHS 0.1, 3, 15, 40, 120, 200, 238, 400, μsec (A, B; D-H)
POLARIZATION Not Specified
RCS ACCURACY ±1 dB (A-C; E, H)
MIN. SNR @ 1000 KM. RANGE, OdBsm TGT 29 dB w/40 μsec pulse (A)
VECTOR UPDATE RATE 20 Hz (C)
PRF 10-2976 Hz (D; A-E, H)

TRACKING ACCURACY
RANGE BIAS 2.0 m (A, B, D)
ANGLE BIAS 250 μrad (A, B, D)
RANGE PRECISION ±0.5 m (A, B, D)
ANGLE PRECISION ±90 μrad (A, B, D)
BEACON TRACK No (A-H)

MISS DISTANCE: YES (A-C)

RADAR/TARGET GEOMETRY
MAX. RANGE 4000 km (A-C, E, H); 37000 km (G)
MIN. RANGE 15 km (A-C)
MAX. ELEV. ANGLE 90° (F, G)
MIN. ELEV. ANGLE 5° (F, G)

TARGET COMPLEX
MAX. NO. OF TARGETS 16 (C)
MIN. RCS -25 dBsm (C, D)
MAX. COMPLEX DIMENSIONS: RANGE 300 km (A-C) ANGLE 1.1° (A-C)
MIN. TARGET SEPARATION: RANGE 100 m (D) ANGLE .15° (A, B)
MANEUVERING TARGET (ACCEL.) YES (A, C)

IMAGING YES ____ NO (X)
RANGE RESOLUTION N/A
AZIMUTH RESOLUTION N/A

OTHER
Simultaneous collection at VHF and UHF (G)

TABLE 2-3

RADAR USER NEEDS

CENTER FREQUENCY: L BAND

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC *
(D) USSPACECOM *
(E) USAF/SAC *
(F) NASA *
(G) DNA
(H) USAF/SSD *
* No Needs

FUNCTIONS
METRIC X SIGNATURE X OTHER ____

OUTPUT DATA
MAX. BANDWIDTH 285 MHz (A, B); 1400 MHz (G)
PULSE LENGTHS 2,50 μsec (A, B, G)
POLARIZATION Not Specified
RCS ACCURACY +/- 1 dB (A, B)
MIN. SNR @ 1000 KM. RANGE, 0dBsm TGT 25 dB (G)
VECTOR UPDATE RATE 10 Hz (A, B, G)
PRF 1499 Hz (A, B)

TRACKING ACCURACY
RANGE BIAS 1.5 m (A, B)
ANGLE BIAS 80 μrad (A, B)
RANGE PRECISION ±.03 m (A, B)
ANGLE PRECISION 80 μrad (A, B)
BEACON TRACK No (A, B)

MISS DISTANCE: Yes (A)

RADAR/TARGET GEOMETRY
MAX. RANGE 2000 km (A, B); 37,000 (G)
MIN. RANGE 15 km (A, B)
MAX. ELEV. ANGLE 90° (G)
MIN. ELEV. ANGLE Horizon (A, B)

TARGET COMPLEX
MAX. NO. OF TARGETS 6 (A)
MIN. RCS Not Specified
MAX. COMPLEX DIMENSIONS: RANGE 300 km (A, B) ANGLE 0.6° (A, B)
MIN. TARGET SEPARATION: RANGE 600 m (A, B) ANGLE 0.15° (A, B)
MANEUVERING TARGET (ACCEL.) Yes (A)

IMAGING YES ____ NO (X)
RANGE RESOLUTION N/A
AZIMUTH RESOLUTION N/A

OTHER

Need also exists for Multi-static Measurement System (MMS).

TABLE 2-4

RADAR USER NEEDS

CENTER FREQUENCY S BAND

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC
(F) NASA
(G) DNA
(H) USAF/SSD

FUNCTIONS
METRIC X SIGNATURE X OTHER ______

OUTPUT DATA
MAX. BANDWIDTH 250 MHz-stepped (A, B, E-H)
PULSE LENGTHS 3 μsec, 9 μsec (A, B, E-H)
POLARIZATION Not Specified
RCS ACCURACY ±1 dB (A-H)
MIN. SNR @ 1000 KM. RANGE, OdBsm TGT 27 dB (A-H)
VECTOR UPDATE RATE 20 Hz (C)
PRF 100-1499 (A, B, E-H)

TRACKING ACCURACY
RANGE BIAS 1.5 m (A, E-H)
ANGLE BIAS No angle track
RANGE PRECISION ±.03 m (A, E-H)
ANGLE PRECISION N/A
BEACON TRACK No (A-H)

MISS DISTANCE: Yes (A, C)

RADAR/TARGET GEOMETRY
MAX. RANGE 4000 km (A, B)
MIN. RANGE 15 km (A, B)
MAX. ELEV. ANGLE 90° (D)
MIN. ELEV. ANGLE Horizon (A, B)

TARGET COMPLEX
MAX. NO. OF TARGETS 6 (A, B)
MIN. RCS -25 dBsm (C, D)
MAX. COMPLEX DIMENSIONS: RANGE 300 km (A, B) ANGLE 0.3° (A, B)
MIN. TARGET SEPARATION: RANGE 100 m (C) ANGLE 0.15° (A, B)
MANEUVERING TARGET (ACCEL.) Yes (A, C)

IMAGING YES ____ NO (X)
RANGE RESOLUTION N/A
AZIMUTH RESOLUTION N/A

OTHER

TABLE 2-5

RADAR USER NEEDS

CENTER FREQUENCY C-BAND

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC
(F) NASA
(G) DNA *
(H) USAF/SSD
* No Needs

FUNCTIONS
METRIC X SIGNATURE X OTHER

OUTPUT DATA
MAX. BANDWIDTH 512 MHz (A, B, E, F, H)
PULSE LENGTHS 10.2 μsec (A, B), 10 μsec (E, F, H);
** .25, .5, 1.0, 5.0 μsec (A, B)
POLARIZATION Not Specified
RCS ACCURACY ±1 dB (A-C, H)
MIN. SNR @ 1000 KM. RANGE, OdBsm TGT 23 dB (A-D, H)
VECTOR UPDATE RATE 20 Hz (C)
PRF 38-400 Hz (A, B, E, F, H)**

TRACKING ACCURACY
RANGE BIAS 8.8 m (A, B, E, F, H)**
ANGLE BIAS 59 μrad (A, B, E, F, H)**
RANGE PRECISION ±9.3 m (A, B, E, F, H)**
ANGLE PRECISION ±150 μrad (A, B, E, F, H)**
BEACON TRACK Yes (A-F); 4 (A)

MISS DISTANCE: YES (A, C)

RADAR/TARGET GEOMETRY
MAX. RANGE 3000 km (D)**
MIN. RANGE 15 km (A-C)
MAX. ELEV. ANGLE 90° (D)
MIN. ELEV. ANGLE horizon (A-C, E,H)

TARGET COMPLEX
MAX. NO. OF TARGETS 3 (A)
MIN. RCS -38 dBsm (C)
MAX. COMPLEX DIMENSIONS: RANGE 2100 m (A) ANGLE 3° (A)
MIN. TARGET SEPARATION: RANGE 600 m (A) ANGLE 0.3° (A)
MANEUVERING TARGET (ACCEL.) YES (A, B)

IMAGING YES X (D) NO
RANGE RESOLUTION Current Capability
AZIMUTH RESOLUTION Current Capability

OTHER
** USAF/BSD and USN/SSP call out specific requirements for FRQ-19 and MPS-36 (presumably because of cost). USSPACECOM seeks greater availability of imaging radars.

TABLE 2-6

RADAR USER NEEDS

CENTER FREQUENCY ____ X-BAND ____

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC *
(F) NASA *
(G) DNA *
(H) USAF/SSD *
* No Needs

FUNCTIONS
METRIC X SIGNATURE X OTHER ____

OUTPUT DATA
MAX. BANDWIDTH 1 GHz (C, D)
PULSE LENGTHS Not Specified
POLARIZATION Not Specified
RCS ACCURACY ±1 dB (A, B)
MIN. SNR @ 1000 KM. RANGE, 0dBsm TGT 35 dB (D)
VECTOR UPDATE RATE 10 Hz (D)
PRF 1000 Hz (A, B)

TRACKING ACCURACY
RANGE BIAS 1.5 m (D)
ANGLE BIAS 100 μrad (D)
RANGE PRECISION .001 m (A, B)
ANGLE PRECISION ±100 μrad (A, B, D)
BEACON TRACK Yes (C)

MISS DISTANCE: YES (A, C)

RADAR/TARGET GEOMETRY
MAX. RANGE 300 km (A, B)
MIN. RANGE 15 km (A, B)
MAX. ELEV. ANGLE 90° (D)
MIN. ELEV. ANGLE Horizon (A, B)

TARGET COMPLEX
MAX. NO. OF TARGETS 20 (C)
MIN. RCS -38 dBsm (C)
MAX. COMPLEX DIMENSIONS: RANGE 300 km (A, B) ANGLE 3° (A, B)
MIN. TARGET SEPARATION: RANGE 5 m (C) ANGLE .15° (A, B)
MANEUVERING TARGET (ACCEL.) YES (A)

IMAGING YES (X) NO ____
RANGE RESOLUTION Current ALCOR (D)
AZIMUTH RESOLUTION Current ALCOR (D)

OTHER
Simultaneously image more than one object (D).

USSPACECOM (D) seeks greater availability of imaging radar.

TABLE 2-7

RADAR USER NEEDS

CENTER FREQUENCY Ka-Band

USER LABEL
(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC
(F) NASA
(G) DNA
(H) USAF/SSD

FUNCTIONS
METRIC X SIGNATURE X OTHER ______

OUTPUT DATA
MAX. BANDWIDTH 1 GHz, current; 2 GHz, future (A-E, H)
PULSE LENGTHS 50 μsec (A-E, H)
POLARIZATION Not Specified
RCS ACCURACY ±2 dB (A-E, H)
MIN. SNR @ 1000 KM. RANGE, 0dBsm TGT 25 dB (C, D)
VECTOR UPDATE RATE 20 Hz (C)
PRF 2000 (A-E, H)

TRACKING ACCURACY
RANGE BIAS 1.5 m (A-E)
ANGLE BIAS 40 μrad (A-E)
RANGE PRECISION ±.03 m (A-E)
ANGLE PRECISION ±40 μrad (A-E)
BEACON TRACK No (E, H)

MISS DISTANCE: YES (A, C, H)

RADAR/TARGET GEOMETRY
MAX. RANGE 3,000 km (D) would like (19000 km) (D)
MIN. RANGE 15 km (A, C, E,)
MAX. ELEV. ANGLE 90° (D)
MIN. ELEV. ANGLE horizon (A, C, E, H)

TARGET COMPLEX
MAX. NO. OF TARGETS 1 (A-E)
MIN. RCS -38 dBsm (C)
MAX. COMPLEX DIMENSIONS: RANGE 10 km (D) ANGLE 0.3° (A)
MIN. TARGET SEPARATION: RANGE Not Spec. ANGLE Not Spec.
MANEUVERING TARGET (ACCEL.) Not Specified

IMAGING YES (X) NO ______
RANGE RESOLUTION Current Capability (D)
AZIMUTH RESOLUTION Current Capability (D)

OTHER
USSPACECOM seeks greater availability of imaging radars.

used, the phrase "not specified" has been entered. In general, radar requirements come from a broad spectrum of users as indicated in Tables 2-1 through 2-7.

2.3 PASSIVE RF DATA NEEDS

Passive radio frequency user requirements are listed in Table 2-8. NASA is the only user which has defined a need for such a capability and that is at either S-band or X-band. No user has specifically defined a requirement for passive RF at W-band (95 GHZ).

2.4 OPTICAL DATA NEEDS

Tables 2-9 through 2-13 contain the user needs in the various optical spectral regions. The needs are grouped into three general categories: geometric, radiometric, and sensor platform characteristics. Where available, needs are specified separately for the late midcourse and reentry phases of ballistic flight.

User needs at ultra-violet and visible wavelengths are provided in Tables 2-9 and 2-10, respectively. Few details have been provided for UV requirements. Ultra-violet requirements appear to come solely from USN/SPP. Visible spectrum requirements come frc⁻ a much broader range of users.

Short, medium and long wavelength infrared user needs are shown in Tables 2-11 through 2-13. Although user IR requirements are not fully defined, they are at a considerably more mature stage than those for UV. As with visible spectrum requirements, IR needs come from a variety of users for each of the three infrared bands.

All of the optical user needs shown in Tables 2-9 through 2-13 were specified for either aircraft- or balloon-borne sensors. Presumably, this reflects the users' understanding that atmospheric effects frequently preclude collection of useful optical signature data (particularly in the IR regions) from ground-based sensors. Some

TABLE 2-8

PASSIVE RADIO FREQUENCY USER NEEDS

FREQUENCY	X or S (F)		USER LABEL
	VHF and L (G)		(A) USAF/BSD
			(B) USN/SSP
			(C) USASDC
ANTENNA REQUIREMENTS			(D) USSPACECOM
			(E) USAF/SAC
DIAMETER	>/= 9m (F)		(F) NASA
MAX. ELEVATION	90° (F)		(G) DNA
MIN. ELEVATION	5° (F)		(H) USAF/SSD
SLEW RATES	>/= 1°/sec (F)		
POINTING ACCURACY	3 arcmin (F)		

Table 2-9

ULTRA-VIOLET USER NEEDS (below 0.4 μm)

		Late Midcourse Phase	Reentry Phase
Geometric			
Field of View	Acq		
	Track		
Angular Accuracy			
Elevation	Max		
	Min		
Slew Rate			250 mrad/s (B)
Frame Rate			≤ 200 Hz (B)
Radiometric			
Spectral Band (s)			Narrow Bands (B) 0.2-0.4 μm (A)
Range	Max		~300 km**
	Min		~15 km (A,C)
Illumination	Target		D/N**
	Sky		D/N?**
Size			
Emissivity			~0 to 1 (B)
App Temp			
Resolution			2m at lower alt.(B)
SNR			≥10 dB (B)* tracking ≥20 dB (B)* data
Dynamic Range			10^6 (A)
Platform Characteristics			
Altitude			
Time-on-Station			
Positional Accuracy			
Com			

User Label
- A) USAF/BSD
- B) USN/SSP
- C) USASDC
- D) USSPACECOM
- E) USAF/SAC
- F) NASA
- G) DNA
- H) USAF/SSD

*ERIM Interpretation **ERIM Supplied

Table 2-10

VISIBLE USER NEEDS (0.4-0.7 μm)

		Late Midcourse Phase	Reentry Phase
Geometric			
Field of View	Acq	10 mrad (A,D)	10 mrad (A,D)
	Track	.5 mrad (A,D)	.5 mrad (A,D)
Angular Accuracy			
Elevation	Max		
	Min		
Slew Rate		70 mrad/s**	250 mrad/S (B)
Frame Rate		10-30 Hz(A,C,D);≤200 Hz(B)	≤200 Hz(B); ≥10 Hz (A,C)
Radiometric			
Spectral Band (s)		0.4 μm (A,C,D) to	0.7 μm (A,C,D)
Range	Max	2000 nmi (D)	~300 km**
	Min	~100 nmi**	~15 km (A,C)
Illumination	Target	D**	D/N*
	Sky	Night**	D/N**
Size		.5 m^2 (C)*	
Emissivity		~0 to 1	
App Temp		NA	
Resolution		100 m (D)	2 m at lower alt.(A,B)*
SNR		≥10 dB (B)	≥10 dB (B)
Dynamic Range		-----------10^6*	(A)----------
Platform Characteristics			
Altitude		≥40 kft ------------------ ≥100 nmi (D)	(A,B,C)
Time-on-Station		6 hours	6 hours
Positional Accuracy			
Com			

User Label
- A) USAF/BSD
- B) USN/SSP
- C) USASDC
- D) USSPACECOM
- E) USAF/SAC
- F) NASA
- G) DNA
- H) USAF/SSD

*ERIM Interpretation **ERIM Supplied

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Table 2-11

SHORT WAVE AND MID WAVE INFRARED USER NEEDS
(0.7-3.0 μm + 3.0-5.0 μm)

		Late Midcourse Phase	Reentry Phase
Geometric			
Field of View	Acq	10 mrad---------------------------(A)	
	Track	0.5 mrad--------------------------(A)	
Angular Accuracy			
Elevation	Max		
	Min		
Slew Rate		70 mrad/s**	≥250 mrad/s (B)
Frame Rate		≥10 (A,C)	30 Hz (B)
Radiometric			
Spectral Band (s)		0.7-1.1, 1.4-2.5, 2.9-3.8 μm (A) --------------NB 2-5 μm----- (B) ------------0.7-5.0 μm------ (C)	
Range	Max	1000 km*	~300 km**
	Min	~200 km**	~15 km (A,C)
Illumination	Target	D/N**	D/N**
	Sky	D/N**	D/N**
Size		0.5 m^2 (C)	
Emissivity		~0 to 1	~0 to 1
App Temp		300 K (B,C)	
Resolution		300-2100 m(A,B,C)	2 m (A,B)
SNR			10 dB tracking 20 dB data (B)
Dynamic Range		-------------10^6*(A)-----------	
Platform Characteristics			
Altitude		≥40 kft-----------------(A,B,C)	
Time-on-Station		6 hours-----------------(A,B)	
Positional Accuracy			
Com			

User Label

A) USAF/BSD
B) USN/SSP
C) USASDC
D) USSPACECOM
E) USAF/SAC
F) NASA
G) DNA
H) USAF/SSD

*ERIM Interpretation **ERIM Supplied

Table 2-12

LONG WAVE INFRARED USER NEEDS (5-13 μmeters)

		Late Midcourse Phase	Reentry Phase
Geometric			
Field of View	Acq	10 mrad----------------------(A,D)	
	Track	0.5 mrad---------------------(A,D)	
Angular Accuracy			
Elevation	Max		
	Min		
Slew Rate		70 mrad/s**	≥250 mrad/s (C)
Frame Rate		≥10 Hz(A,B,C)-30 Hz(D)	≥10 Hz (A,B,C)
Radiometric			
Spectral Band (s)		10.5-12.7 μm; 5.5-9.0 μm (A) --------------8-12 μm (B)--- ------------5-9.8 μm (C)---- 6-11 μm (D)	
Range	Max	4000 km* (D)	~300 km**
	Min	200 km**	~15 km (A,C)
Illumination	Target	D/N**	D/N**
	Sky	D/N**	D/N**
Size		0.5 m^2 (C)	
Emissivity		~0 to 1	
App Temp		~270 K* (D)	
Resolution		100 m (D)	2 m at lower alt. (A,B)
SNR		8 dB (D)	20 dB (B)
Dynamic Range		100 (A)	10^6 (A)
Platform Characteristics			
Altitude		100 n miles (D) 40 kft-----------------(A,B,C)	
Time-on-Station		6 hours----------------(A,B)	
Positional Accuracy			
Com			

User Label
A) USAF/BSD
B) USN/SSP
C) USASDC
D) USSPACECOM
E) USAF/SAC
F) NASA
G) DNA
H) USAF/SSD

*ERIM Interpretation **ERIM Supplied

Table 2-13

LONG LONG WAVELENGTH INFRARED USER NEEDS (13-24 μmeters)

		Late Midcourse Phase	Reentry Phase
Geometric			
Field of View	Acq	10 mrad-------------------(A)	
	Track	0.5 mrad------------------(A)	
Angular Accuracy			
Elevation	Max		
	Min		
Slew Rate		70 mrad/s**	≥250 mrad/s (B)
Frame Rate		≥10 Hz---------------(A,B,C)	
Radiometric			
Spectral Band (s)		-------------18-24 μm (A,B)-----	
		-------------16-21 μm (C)-------	
Range	Max	3000 km*	300 km**
	Min	200 km**	50 km**
Illumination	Target	D/N**	D/N**
	Sky	D/N**	D/N**
Size		0.5 m^2	
Emissivity		~0 to 1	
App Temp		300 K (A,B,C)	
Resolution		300-2100 m (A,B,C)	2 m (A,B)
SNR		20 dB (D)	20 dB (C)
Dynamic Range		100 (A)	10^6 (A)
Platform Characteristics			
Altitude		≥40 kft----------------(A,B,C)	
Time-on-Station		6 hours---------------(A,B)	
Positional Accuracy			
Com			

User Label
A) USAF/BSD
B) USN/SSP
C) USASDC
D) USSPACECOM
E) USAF/SAC
F) NASA
G) DNA
H) USAF/SSD

*ERIM Interpretation **ERIM Supplied

users did request photodocumentation data from the locations of existing USAKA RADOTs and Super-RADOTs, but gave no specific technical requirements for these. It was therefore assumed that the existing USAKA optical sensors are adequate for meeting ground-based data collection requirements. The optical shortfall analysis thus focussed on the airborne platform data needs represented by Tables 2-9 through 2-13.

In addition to the user needs listed in the tables, there is a stated need by USASDC for spectral radiant intensities over the range 5-25 micrometers collected from a sounding rocket platform. No specific technical specifications related to this requirement were reported. A capability for such measurements exists and has been utilized at USAKA. However, no routine capability of this type is expected to be utilized or required at USAKA. Due to this fact, as well as the lack of specific user needs, the issue of spectral data requirements is not addressed further in this report.

2.5 ENVIRONMENTAL AND TELEMETRY DATA NEEDS

Several users are concerned about weather conditions, and especially atmospheric water content and particle size, at or very near the reentry point during a mission. These measurements provide the determination of the Weather Severity Index (WSI) and potential impact on RV performance over the reentry path. Reentry dispersion may be caused by conditions related to the environment and it is desirable to measure conditions along the reentry path at intervals not exceeding 1000 ft. Wind velocity and density data need to be measured as near the time of mission events as possible. Liquid water content measurements should include estimates of particle size distribution and measurement uncertainties for each cloud penetrated along the reentry corridor.

Refraction effects within the troposphere cause errors in the measurements of elevation and range. These errors vary due to a gradual increase in the refractive index with decreasing altitude. Models updated by physical measurements to isolate these errors are required for some missions. No accuracy requirements are stated, but the obtained accuracy must be consistent with measured accuracies of temperature and density. User needs for environmental (meteorological) data are provided in Table 2-14 in terms of a list of environmental measurement parameters and their accuracies.

The majority of users have the requirement for telemetry for the collection of on-board multiple sensor data. The collection of on-board sensor data such as accelerometers or rate-gyros is used to further augment the determination of flight dynamics measured by other remote imaging sensors. The time of impact is also needed by the users and is determined by timing the loss of the telemetry signal received from the vehicles. Furthermore, the acquisition of on-board sensors data provides the occurrence and time of the arming and fusion event.

Most users require that the acquisition of the telemetry signal occur at the earliest time possible, such as at horizon break if the vehicle was launched from the CONUS, or immediately after launch if a vehicle was launched from a USAKA location. Recording of the telemetry signals will occur until demise. These are indications that some users will have more multiple instrumented reentry vehicles which will require additional telemetry tracking, simultaneously. In addition, there will be more sensors with an increase in the data transmission bandwidth. Other future programs, such as ERIS, expect to use up to five separate telemetry links with data transmission rates ranging from 2 to 20 Mbps. Telemetry needs are shown in Table 2-15 and represent, primarily, the number of telemetry data links and their required data rates.

TABLE 2-14

ENVIRONMENTAL DATA USER NEEDS

MEASUREMENT ACCURACIES - SURFACE

TEMPERATURE	.1°C
REL. PRESSURE	.1%
WIND SPEED AND DIRECTION	.1%
RELATIVE HUMIDITY	3%
REFRACTIVE INDEX	

MEASUREMENT ACCURACIES TO 100kft

TEMPERATURE	.3°C
REL. PRESSURE	.5%
WIND SPEED AND DIRECTION	.5%
RELATIVE HUMIDITY	6 F/S
COMPONENT	

MEASUREMENT ACCURACIES ABOVE 100kft

TEMPERATURE	.6°C
WIND SPEED AND DIRECTION	1.0%
RELATIVE HUMIDITY	10 F/S
RELATIVE PRESSURE	

USER LABEL

(A) USAF/BSD
(B) USN/SSP
(C) USASDC
(D) USSPACECOM
(E) USAF/SAC
(F) NASA
(G) DNA
(H) USAF/SSD

Table 2-15

TELEMETRY USER NEEDS

Output Data	USER LABEL
Polarization - RC, LC (A, E)	(A) USAF/BSD
Data Rate - 250-500 Kbs (A,E)	(B) USN/SSP
Data Rate - 2-20 Mbps (USASDC ERIS Program)	(C) USASDC
Data Encryption - Yes	(D) USSPACECOM
Bandwidth - 1.5 MHz (A-E)	(E) USAF/SAC
Bandwidth - 60 MHz (USASDC ERIS Program)	(F) NASA
Center Frequency - 2263.5, 2288.5, 2275.5, 2221.5, 2250.5 MHz (E)	(G) DNA
Number Data Links - 3 (E)	(H) USAF/SSD
Number Data Links - 5 (USASDC ERIS Program)	
Frequencies - S-Band (2.3-2.4 GHz) (A-E)	
Coverage - Acquisition of signal (AOS) to 200 μsec post impact or loss of signal (LOS) (A-E)	
Modulation - PCM/FM (A-E)	

3.0 USAKA CAPABILITIES

3.1 OVERVIEW

USAKA capabilities include long range tracking and signature radars, a variety of optical instruments and cameras, impact scoring systems, and supporting services including telemetry and meteorological measurement capabilities. Each of these is described by a brief narrative below in sections 3.2 through 3.6. Section 3.7 provides a functional description of these capabilities from the standpoint of metric measurements (target tracking, location determination and target microdynamics). Section 3.8 addresses target signature measurements from the functional standpoint of amplitude and spectral characteristics provided by the available USAKA instrumentation. The functional aspects of the supporting services are summarized in section 3.9. The USAKA capabilities description is concluded by a tabular summary of quantitative information on capabilities (Sections 3.10 through 3.12) in formats similar to those used for the "Users Needs" in section 2.0.

3.2 RADAR RESOURCES

USAKA radar systems, which are part of the USAKA data acquisition system, are primarily located at the Kiernan Reentry Measurement Site (KREMS). The KREMS sensors are all located on Roi-Namur Island, and consist of the ARPA-Lincoln C-Band Observables Radar (ALCOR), the ARPA-Long Range Tracking and Instrumentation Radar (ALTAIR), the Target Resolution and Discrimination Experiment (TRADEX) radar, and the Millimeter Wave Radar (MMW). The other USAKA data acquisition radars are the AN/FPQ-19 located on Kwajalein island, and AN/MPS-36's located on Kwajalein and Illeginni. The locations of these radar resources are shown in Figure 3-1.

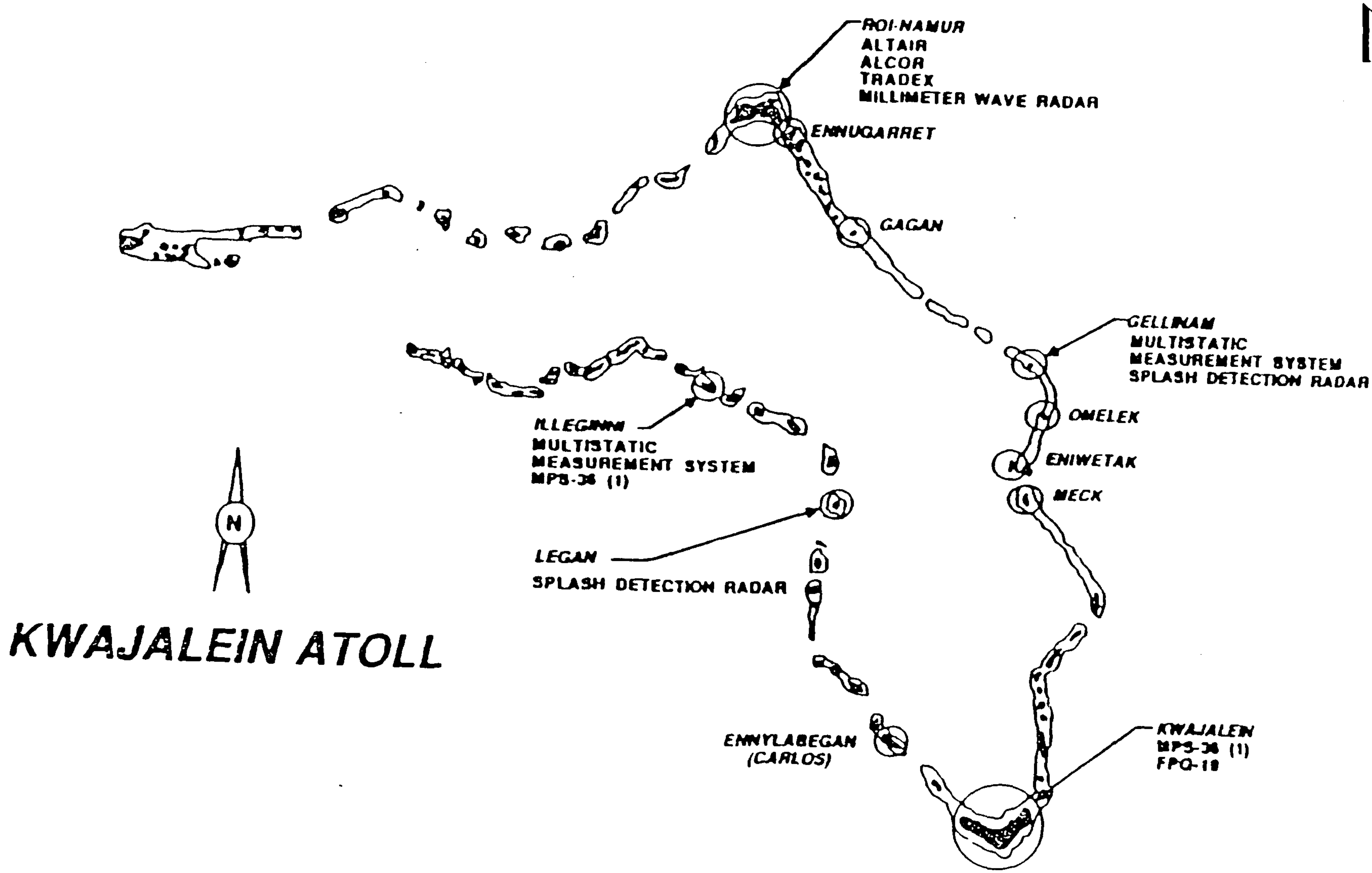

Figure 3-1. RADARS

The radars located on Roi-Namur are under the direction of the KREMS Control Center (KCC) also located on Roi-Namur and support both reentry and space track missions. KCC is under the direction of the Range Operations Control Center (ROCC), located on Kwajalein, which is in direct contact with Honolulu and the range user. ROCC also maintains constant contact with the Range Safety Center (RSC) during all mission activities. When ALTAIR is not supporting USAKA missions, the deep space surveillance radar responds directly to the Air Force 24 hrs/day, 7 days/week.

During a reentry mission, ALTAIR is often used to initially detect incoming vehicles, and the other sensors are initially slaved to ALTAIR via the KCC data bus. Later, the other sensors may be slaved to ALCOR which will provide pointing vectors to different vehicles based upon beacon track information. ALCOR and MMW may also be used to discriminate targets when beacon tracks are not part of the mission profile. The following sections more fully describe each system. A summary table of radar parameters is provided at the end of this section.

3.2.1 ALTAIR (VHF and UHF)

ALTAIR is a VHF (153 to 162 MHz) and UHF (415 to 440 MHz) radar utilizing a 45.72 meter diameter paraboloid reflector antenna, 5.5 meter diameter frequency selective subreflector (FSS), and a 5-horn monopulse feed for VHF and a Multi-Mode monopulse feed for UHF. The ALTAIR system was designed and developed to gather coherent data on reentry vehicles and satellites at VHF and UHF frequencies. This high-sensitivity, wide-beamwidth instrumentation radar extends the USAKA reentry measurements radar capability with its wide-dynamic range, good range resolution, multiple-target range tracking, and high PRF. ALTAIR possesses monopulse tracking capability in both the VHF and UHF bands and can range track up to 32 VHF and UHF in-beam targets. Typically the VHF band is used for initial acquisition and UHF is used for gathering metric and signature data. ALTAIR's primary task is that of acquisition of reentry vehicles at far range, because of its large beam width, and then passing target vector data to the other sensors for acquisition. After initial acquisition ALTAIR may be utilized to obtain metric and signature data on all incoming vehicles and chaff. ALTAIR can also operate in a bistatic mode on UHF using the UHF receiver on Gellinam (only) which is part of the Multistatic Measurement System (MMS). See TRADEX for further information on MMS.

3.2.2 TRADEX (L-band and S-band)

TRADEX provides L-band (1320 MHz) and S-band (2950.8 MHz) skin tracking utilizing a number of waveforms with varying pulsewidths and bandwidths. TRADEX employs a 25.6 meter diameter antenna with a 5-horn monopulse feed for L-band and a coaxially mounted circular horn for S-band. Normally, when tracking, the S-band is slaved to the L-band since S-band only tracks in range. Typical requirements for TRADEX include metric and signature data on vehicles and chaff.

The Multistatic Measurement System (MMS) was added as an adjunct to TRADEX primarily to increase the tracking accuracies in L-band by adding a bistatic measurement capability. The MMS system consists of two additional receiving stations located on Illeginni and Gellinam which are slaved to TRADEX. The MMS L-band receivers use returns from target vehicles illuminated by TRADEX and pass bistatic data to TRADEX.

3.2.3 ALCOR (C-band)

ALCOR is a C-band, high power, narrow beam, coherent, chirped, monopulse tracking radar with a 5664 Mhz narrowband and 5672 Mhz wideband operating mode, each having separate signal designs. ALCOR utilizes a 12.2 meter diameter reflector with a 4-horn monopulse Cassegrain feed. ALCOR can function as an independent tracker or accept target designation data from other radars. It is capable of tracking only one object in angle, but can simultaneously range track two separate objects -- one in narrowband, the other in wideband. A C-band beacon system is installed to assist in acquiring beacon equipped targets. The beacon mode can track in both range and angle. ALCOR is also a weather measurement radar with TRADEX designated as backup when weather data is requested. ALCOR may obtain metric and signature data on vehicles or chaff, generate images of satellite and reentry vehicles, perform weather scans, or track incoming vehicles using the beacon interrogation system and pass the appropriate pointing vector to another sensor.

3.2.4 Millimeter Wave (Ka-band and W-band)

The MMW is a dual frequency (35 GHz and 95.5 GHz) very narrow beam, monopulse tracking radar characterized by high range and doppler resolution, high sensitivity, precise pointing and tracking, and waveform flexibility. Utilizing a 13.7 meter diameter reflector and a four horn monopulse feed for Ka-band and a single horn feed with a frequency selective subreflector (FSS) for W-band, the radar can function as an independent target tracker or, through the KREMS sensor network, may exchange target designation data with other KREMS or USAKA sensors. By virtue of its 1 GHz signal bandwidth in both the Ka- and W-bands, it achieves a range resolution of .28 m, including the pulse-broadening effects of signal spectral weighting for range sidelobe suppression. In addition, it possesses excellent Doppler resolution (.214 m/s in Ka and .078 m/s in W) resulting in two dimensional imaging capabilities of satellites and reentry vehicles. Target acquisition, range and angle tracking and high-resolution data reception occurs at Ka-band, while wideband data reception only (i.e. no tracking) takes place at W-band.

3.2.5 AN/FPQ-19 (C-band)

The FPQ-19 Radar System is a C-band (5400 to 5900 MHz), long range, amplitude comparison, monopulse radar capable of manual or automatic RF or manual optical tracking. It is used as a beacon and skin tracking radar and is capable of simultaneously range tracking two targets within the beam in any combination of skin or beacon modes. It provides radar range, azimuth, and elevation; video azimuth and elevation data in X-Y coordinate digital form; and digital in-phase and quadrature video for phase derived range data for targets with a signal-to-noise ratio greater than 0 dB. The FPQ-19 can provide angular track of targets using video detection and error determination. It can be initially designated to a target by four methods: (1) designation by another range sensor using pointing data provided through the ICC; (2) computer-generated predictions of target position and dynamics from the ICC; (3) computer predictions of target position and dynamics generated locally on the FPQ-19 MODCOMP processor; and (4) through slaving to the manually operated MK-51 optical tracker.

3.2.6 AN/MPS-36 (C-band)

There are two MPS-36 general purpose, mobile C-band instrumentation tracking radars: one located on Kwajalein Island and one on Illeginni Island. Each MPS-36 radar operates on a frequency band of 5400 to 5900 MHz, utilizing a 3.7 meter diameter reflector and a 5-horn monopulse feed. The system is designed to rapidly acquire and automatically track either skin or beacon targets. The MPS-36 provides metric data on incoming missions and local launches in either skin or beacon track modes, provides real time acquisition and tracking data to other range instrumentation sensors, and furnishes tracking data on weather balloons and meteorological rocket payloads. The radar is used primarily as a beacon tracking radar due to the limited radar sensitivity inherent with the system. The radar has been modified to interrogate the special OBLSS beacon (non-IRIG) and has lead/trail edge range tracking capability in the skin mode (SN-3 only).

3.3 VISIBLE OPTICAL RESOURCES

Precise photographic instrumentation data on missile performance is provided for support of Range operations by tracking camera stations, ballistic cameras, and special fixed cameras. The tropical conditions common to this area favor employment of photo-instrumentation because of brilliant lighting and strong shadow contrast. However, visibility is generally reduced between the surface and +15 degrees by drifting cumulus clouds. This impedes the acquisition of optical data on incoming vehicles impacting in the broad ocean area at significant distances from the islands in the Atoll with optical instrumentation.

The principal metric measurements supported by the USAKA optical sensors are those related to trajectory estimation. The complete specification of a vehicle trajectory requires measurements of range, elevation and azimuth, each as a function of time. The current optical sensors provide only the latter two quantities, but with the greatest precision and accuracy (approx. 25 microradians) of all the USAKA sensors. The other significant metric measurement that is possible with the USAKA optical sensors is that of RV wake length. The measured angular extent of the wake must be combined with range and aspect angle data to produce an estimate of physical length.

The signature measurements supported by the current USAKA optical sensors include quantitative estimates of RV radiant intensity and qualitative spectral analysis of that intensity. Both measurements are limited to roughly the visible spectrum (380-690 nanometers).

Tracking camera systems consist of Recording Automatic Digital Optical Trackers (RADOTs) and Super RADOTs. Fixed camera systems include the Ballistic Plate Cameras (BC4s), the Spectral Ballistic Plate Cameras (SBCs), and a mix of Motion Picture (MOPIC) and video cameras located on Fixed-Camera towers and mobile units. The location of various optical range instruments around the Atoll is shown in Figure 3.2.

3.3.1 Super-RADOT

The Super-RADOT is a modified version of the RADOT and is designed for closed-loop tracking and precise long-range metric data collection. The primary sensor is an ISIT (intensified silicon intensifier target) video camera capable of measuring RV elevation and azimuth to an accuracy of 25 microradians (after data reduction). This high accuracy results from the use of digital video tracking techniques and a precision tracking mount. The ISIT cameras are sensitive enough to detect 14th magnitude stars; this permits exoatmospheric tracking of objects if they are suitably illuminated.

The secondary sensor on the Super-RADOTs is presently a 70 mm MOPIC camera. Due to film sensitivity limitations, this camera can only provide endoatmospheric tracking. It has an angular measurement accuracy of approximately 55 microradians. Azimuth, elevation, and timing data are recorded on each frame of the 70 mm film. The Super-RADOT is also equipped with a 16 mm Vidicon video camera which is used as an operator aid and for mission documentation purposes.

Initial target acquisition with the Super-RADOT is achieved via designation from one of the range radars. Once acquired, the target may be tracked either manually, in an open-loop mode (i.e. slaved to the designating radar), or in a closed loop mode.

3.3.2 RADOT

The predecessor of the Super-RADOT, the RADOT (Recording Automatic Digital Optical Track) is the other tracking optical sensor currently in use at the USAKA range. Its primary metric sensor is a 70 mm MOPIC camera with f/16 optics (200" focal length) that is identical to the secondary camera of the Super-RADOT. It is also equipped with a second

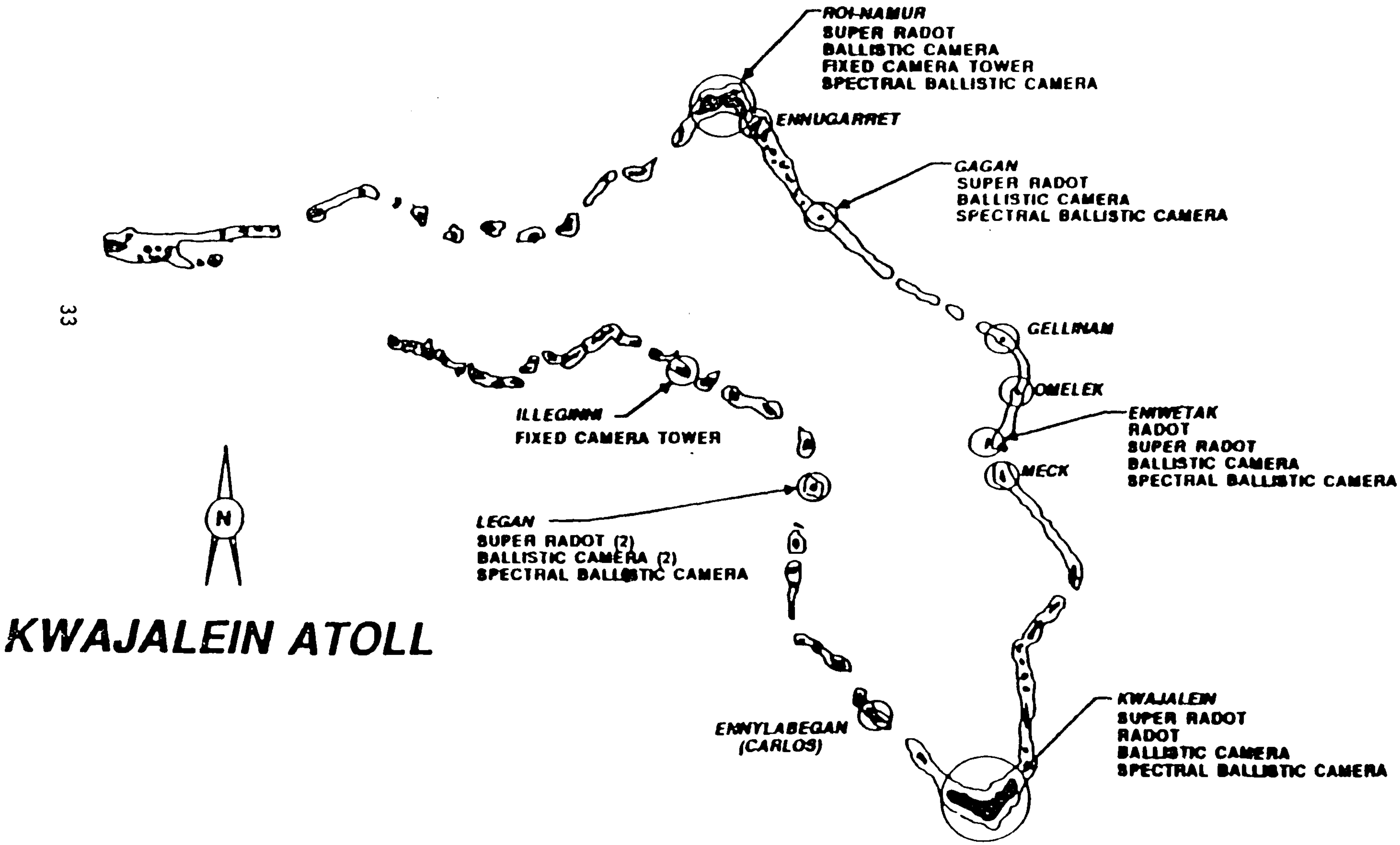

Figure 3-2. OPTICAL SYSTEMS

metric sensor, a 70 mm MOPIC camera with f/8 optics (100" focal length) capable of up to 360 frames per second. Two other color MOPIC cameras, one 35 mm and one 16 mm provide engineering sequential data and documentary data, respectively. The 35 mm camera is capable of very high frame rates, up to 2,500 frames per second. As with the Super-RADOT, the RADOT is also equipped with a documentary video camera.

The use of film-based cameras limits data collection to endoatmospheric targets only. As with the Super-RADOT, elevation, azimuth and timing data are encoded into each frame of the 70 mm film. The angular accuracy achievable with the metric film data is approximately 55 microradians. The RADOT is not capable of closed loop tracking due to lack of video data. Typically, tracking is slaved to external signals provided by one of the range radars.

3.3.3 Ballistic Camera (BC-4)

The BC-4 is a wide field-of-view (45 x 45 degrees) photogrammetric still camera that records multiple exposures of RV position versus time on a single 190 x 215 mm photographic glass plate. It is capable of resolutions exceeding 50 lines/mm near the frame center and 25 lines/mm near the corners with less than .01 mm distortion at the film plate. There are six BC-4 cameras at the USAKA range; each is collocated with one of the Super-RADOTs. The Perkin-Elmer 8/32 computer used to control each Super-RADOT also controls the BC-4 shutter timing providing multiple exposures of RV position. The resulting image appears as a sampled version of the RV trajectory with a uniform pattern of missing samples, which correspond to the capping shutter being triggered, allowing for timing of the RV.

Each BC-4 camera is mounted on a modified Wild T4 theodolite base which permits pointing in azimuth and elevation as required to view the RV trajectory. The sensitivity of the photographic plate limits data collection to endoatmospheric vehicles. The angular accuracy with which RV position can be measured in a BC-4 image is approximately 65 microradians. This accuracy is achieved via angular calibration to stellar targets while the camera is in a mission-oriented position.

3.3.4 Spectral Ballistic Camera (SBC)

The SBC provides qualitative spectral information about the visible radiation emitted by a reentry vehicle from 380 to 690 nm. Its operation is similar to that of the BC-4 camera in that it is a wide FOV (39 x 39 degrees) fixed camera pointed toward the RV trajectory. The recording medium is a 230 x 305 mm glass plate coated with 103F emulsion. The camera optics are equipped with a grating to provide spectral dispersion of the received radiation. The presence of specific emission lines can then be identified via microdensitometer scans of the exposed plate. The plate is repeatedly exposed during the mission so that data from the entire observable trajectory is obtained. The result is a two-dimensional record in which time is one dimension and wavelength is the orthogonal direction. Analysis of the emission spectra as a function of time permits identification of what chemical species were burning at each point in the RV trajectory.

Three grating densities, 90, 150, and 300 lines/mm, are available providing spectral resolutions of 1.33, .8 and .4 nm, respectively. The latter two gratings are the most commonly used. Although the finer gratings (i.e. more lines per mm) provide better spectral resolution, they also record less energy per spectral line. Thus, very weak lines may not be detected with the finer gratings; conversely, very closely spaced lines may not be resolved with the coarser ones. All the gratings are blazed to provide only a primary and a weaker secondary order, both of which are recorded on the photographic plate. The secondary order permits better definition of very strong emissions (e.g., near the end of the RV trajectory) that may cause film saturation in the primary order.

3.3.5 Fixed-Cameras

Apart from the sensors used for metric and signature measurements, a number of USAKA optical sensors exist for the purposes of mission documentation and local observations. These include 16 mm and 35 mm color motion picture cameras, standard and low light level video cameras and still cameras used to collect streak photography of RVs. These systems support a variety of functions including the collection of engineering sequential film for both the early flight performance of locally launched vehicles and the pre-impact coverage of land impact RVs. Other functions include area surveillance and range safety support. The specific sensor systems used for these purposes include fixed camera towers, closed circuit television and mobile documentary systems.

3.4 SCORING SYSTEMS

Scoring systems are used to provide direct measurement of the location of events, such as RV impact.

3.4.1 Splash Detection Radar (X-band)

The SDRs are scanning radar systems specifically designed to detect the splash of a reentry vehicle as it impacts the water surface. The X-band SDR's operate at a frequency of 9.375 GHz with V-V polarization and scan an area of 360 degrees in azimuth. The radars have a clear weather capability of detecting a splash of 9 meters minimum height and three seconds minimum duration from a minimum range of 8 km to a maximum range of 30 km with a detection probability of at least 95 percent. The SDR's are located at Legan (SDR-3) and Gellinam (SDR-7) Islands (Figure 3-3). Scoring coverage is provided in the lagoon area and the broad ocean areas immediately to the east of Kwajalein Atoll and to the west of the lagoon.

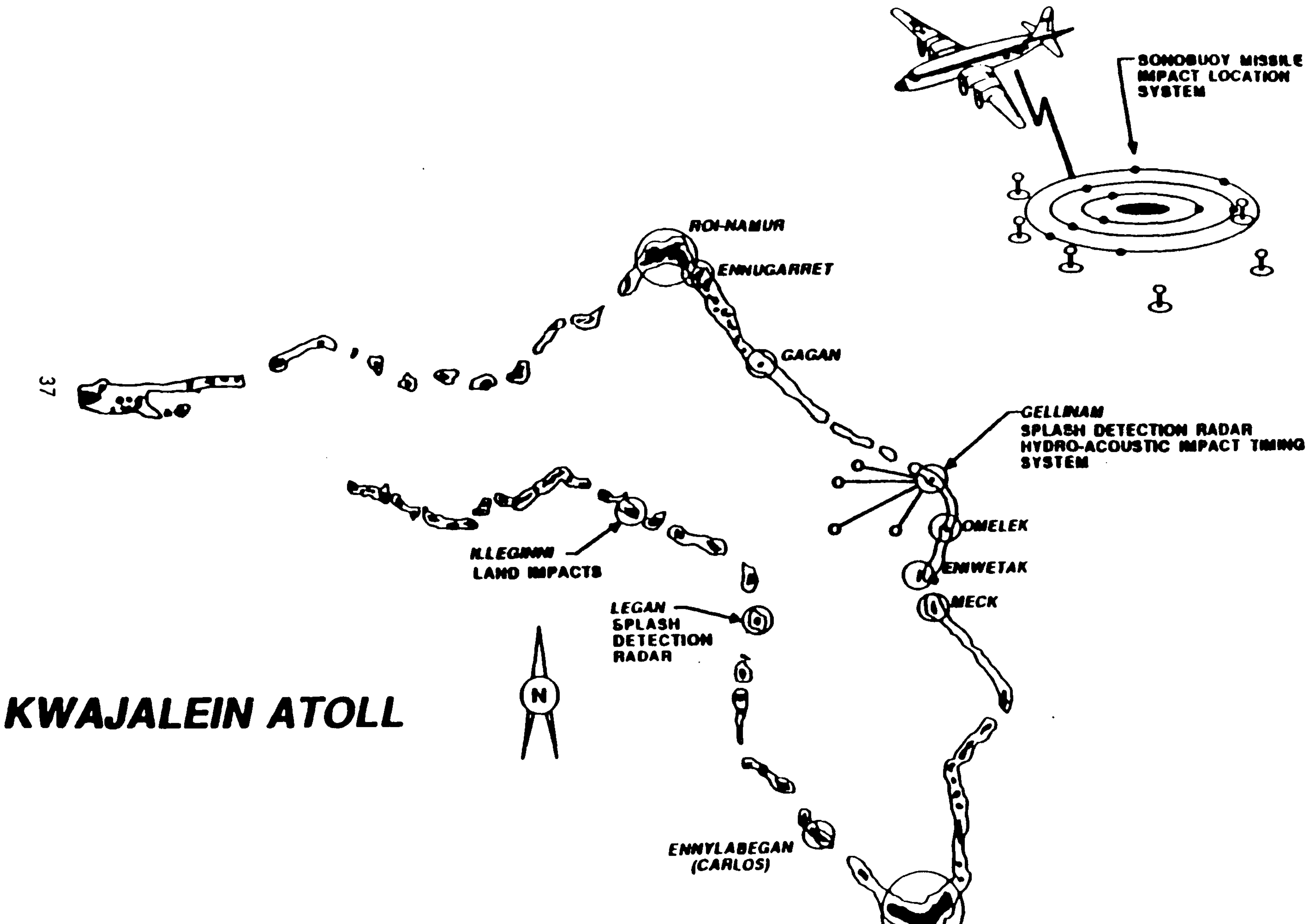

Figure 3-3. SCORING SYSTEMS

3.4.2 HITS (Sonar)

The Hydroacoustic Impact Timing System (HITS) is an underwater sound detection system used to detect and record the impact of an RV on the water surface. The HITS four sensors, each composed of hydrophones and velocimeters, have been placed in storage at Kwajalein and should be able to be reactivated within 14-20 days after activation request. The system has a design impact timing accuracy of ±2.6 milliseconds which corresponds to an impact location of ±4 meters to ±6 meters for the distribution of lagoon targets covered by HITS. However, this system has not been used in over a year and recent attempts to check the instrumentation indicate it may no longer be functional. Sensor locations are west of Gellinam in the lagoon.

3.5 TELEMETRY

USAKA range instrumentation provides capability to receive and record encrypted telemetry signals from appropriately instrumented targets. This section describes resources available for this application.

3.5.1 Overview

USAKA telemetry (TM) ground stations are located on the islands of Ennylabegan (also known as Carlos), Roi-Namur, and Gagan (see Figure 3-4). These locations provide a varied tracking geometry for reentry, orbital and launch operations. All three locations have single channel monopulse 2.2 to 2.3 GHz autotracking antenna systems. USAKA is currently in the process of upgrading the systems to support the new increased S-band IRIG standard bandwidth for telemetry (2.2 to 2.4 GHz).

The Ennylabegan facility is the largest and is capable of receiving, recording, and processing Pulse Code Modulation (PCM/FM and PCM/FM/FM), Pulse Duration Modulation (PDM/FM and PDM/FM/FM), and

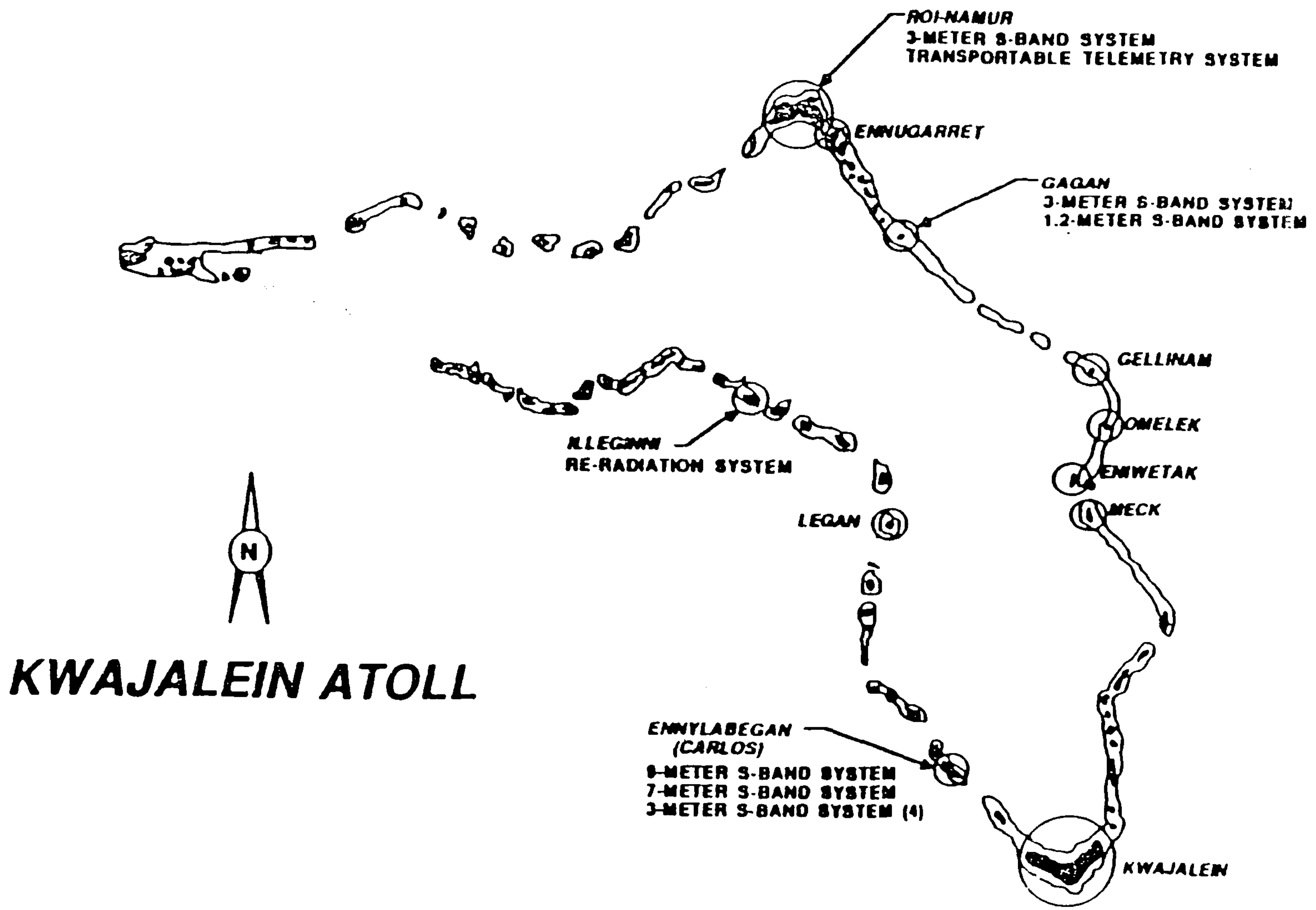

Figure 3-4. TELEMETRY SYSTEMS

Pulse Amplitude Modulation (PAM/FM/PM). The remote station of Gagan is designed as a receive/record station only, but is in the process of being upgraded to include data separation and display facilities. The Roi-Namur station is the second largest TM facility and is capable of receiving, recording, and processing all standard IRIG, PAM, PDM and FM PBW (Pulse Bandwidth) modulations. Roi also has the Transportable Telemetry Station (TTS) consisting of a trailer-mounted antenna system and a separate van housing its electronic equipment. Finally, the Illeginni Re-radiation System is used to receive wideband TM data signals in the 2.2 to 2.3 GHz band and amplify them, down convert them, and retransmit them at L-band to Ennylabegan.

Each target from which TM data is to be gathered must have a dedicated TM frequency and antenna. Predicted trajectory pointing vectors are computed and provided to the TM station by range control and the antennas are pre-positioned for an Acquisition-of-Signal (AOS) when the target breaks the horizon. Radar positioning data is used initially to slave the TM antennas until a high quality link is established (operator judgement), at which time autotracking is initiated.

3.5.2 TM Antennas

There are six telemetry antennas located on Ennylabegan; one 9 meter S-band parabolic reflector autotrack, one 7 meter S-band parabolic reflector autotrack, three 3 meter S-band parabolic mesh autotrack, and one 3 meter S-band parabolic solid autotrack. There are two antennas on Gagan; one 3 meter S-band parabolic reflector autotrack, and one 1.2 meter S-band parabolic reflector fixed. The fixed antenna is positioned in azimuth to support impact telemetry within a 12 mile radius from Gagan. There are two antennas located on Roi-Namur; one 3 meter S-band parabolic reflector autotrack (this antenna can be configured for L-band support), and one transportable/trailer mounted 5.5 meter S-band parabolic reflector autotrack.

3.5.3 TM Receive and Record Equipment

USAKA TM capability includes some 56 receivers, 3 PCM decommutators, 2 PAM/PDM decommutators, 14 analog 14-channel recorders, 22 hot stylus 8-channel recorders, and other equipment. Receive and record Channel capacity is principally determined by a small set of these instruments. The most critical in the data flow are the multicouplers, data receivers, demodulators, diversity combiners, and analog data recorders. The following paragraphs briefly describe these instruments.

The existing multicouplers cover the frequency range of 215 to 315 MHz. The 2.2 to 2.3 GHz signal is down-converted to this range at the antenna. Each multicoupler unit enables coupling of up to eight data receivers to one antenna with low insertion loss between input and output and high isolation between outputs. A total of twelve S-band multicouplers are currently being procured as part of the USAKA TM upgrade to full S-band. This will eliminate the need for down-converting at the antenna. This is expected to be completed in the summer of 1989. This upgrade will provide sufficient outputs to accommodate the GPS/TPS system.

Two data receivers and one diversity combiner are required for each frequency channel to accommodate LHC and RHC polarization. The receivers are of modular construction and each is equipped with standard FM demodulator plug-in units. There are several makes of data receivers and each has its own specifications of frequency, range, bandwidths, and frequency response.

The diversity combiners are used to combine LHC and RHC polarized signals to improve the signal-to-noise ratio. From the receivers and combiners are six outputs which are recorded on the analog tape recorders. Three other signals are used for recording the AGC signal of the two receivers and combiners which are frequency modulated by the data insertion converter signal mixers prior to recording on the FM analog tape recorder.

The 14 track analog magnetic tape recorders have multiple speeds which range from 15/16 to 240 inches per second. Typical mission data is recorded at 120 inches per second on 1-inch wide magnetic tape. Frequency response is 4 MHz direct and 1 MHz FM.

3.6 METEOROLOGICAL OBSERVATION AND FORECASTING CAPABILITIES

3.6.1 Overview

The primary function of the meteorological support group at Kwajalein is weather data acquisition and forecasting in support of missile operations. In addition to scheduled meteorological support for Range Operations, general weather and aviation terminal forecasts are issued on a scheduled basis. Advisories and warnings are issued as required.

The data gathering function consists of the following: taking complete, often specialized, surface observations; making upper air soundings using rawindsondes, meteorological rockets, theodolites and wind finding radars; and tracking and recording data from meteorological satellites and radar observations. Real-time range operations support is provided by a meteorologist in the Range Operations Control Center. Specialized meteorological support is available on request to assist in describing weather criteria for meeting test objectives.

3.6.2 Control Room Data System (CRDS)

The CRDS was developed to define the cloud environment of reentry vehicles, including the tops, bases and water content profiles of clouds in the reentry corridor. Measurements of radar backscatter from clouds in the corridor are made for each reentry vehicle. A cloud model is used to interpret the backscatter measurements in terms of liquid water content. Cloud bases and tops are defined and a general indication of absolute liquid water content is obtained from radar data.

The CRDS is also capable of collecting data from a high altitude instrumented Learjet to make detailed measurements of cloud and precipitation particle spectra at critical points in the reentry area. These measurements are then correlated with radar backscatter measurements. The radar backscatter measurements, taken at reentry times, can then be interpreted in terms of liquid water content to give moisture profiles and environmental severity indices along the reentry trajectory. Photography and optical measurements of clouds and reentry phenomena are also available from the aircraft.

The Learjet also carries a Ka-band Airborne Cloud Characterization Radar (ACCR) which is used to make detailed measurements of the structure of clouds below the aircraft. The capability of the radar is used to interpret the dynamics and microphysical structure of the clouds.

3.6.3 Meteorological Sounding System (MSS)

Two precision MSSs are available on Kwajalein and one on Roi-Namur to provide accurate atmospheric density and wind data. The systems collect meteorological data from sensors deployed by rockets or balloons. When the MSS radiosonde is used, the system is fully automated, feeding digitized tracking and telemetry data into a microprocessor for real-time processing and data reduction. With other radiosondes and rocketsondes, telemetry data are extracted manually from an analog recording and entered into the data processing. For nontransponding rocketsondes, the software accepts a radar track file from the MPS-36 or FPQ-19 radar and merges these data with telemetry data.

3.6.4 WSR-74S Weather Surveillance Radar

The WSR-74S is a pulsed, non-coherent, S-band radar used to detect, analyze, and record precipitating weather systems. The radar has a range of approximately 450 Km and can measure the height, distance, intensity and course of weather systems. The operating frequency is tunable over a range of 2700 to 2900 MHz and the peak power output is 556 Kw. The radar is equipped with a Digital Video Integrator and Processor (DVIP) which automatically processes the received radar data into six levels of intensity categories. The digitized data is transmitted over the Radar Data Remoting System (RDRS) to the ROCC, Control Tower, and Base Operations. It is also transmitted to Vandenberg AFB, California, using normal telephone circuits.

3.6.5 Pilot Balloon (PIBAL) Observations

PIBAL observations are routinely taken at Kwajalein to obtain low-level wind data used in support of meteorological rocket launch operations.

3.6.6 Wind Finding Radar (WF100)

Two wind-finding radars located on Roi-Namur are used to track balloon-borne corner reflectors to provide precise upper level winds. The wavelength of 3 cm allows tracking in clouds or light precipitation. The system includes tower-mounted wind sensors at the 38, 55, 85, 130 and 200 ft levels. The wind data are used to compute launcher settings for Roi-Namur launches.

3.6.7 Meteorological Rocket Observations

Meteorological rockets are used for measurements of atmospheric temperature, wind speed and wind direction over an altitude range of

20 to 70 Km. Pressure and density are computed from the temperature measurements. The sensors are carried to altitude by rocket where they are ejected at the apex of the flight trajectory. These sensors then descend by parachute and transmit telemetry data to the MSS ground station. Wind speed and direction are determined by radar tracking with the MPS-36 or FPQ-19. For measurements at higher altitudes (90 Km), wind, density, and temperature are computed from radar measurements of a falling inflatable sphere (Robin Sphere) inserted at altitude by a rocket.

3.6.8 GOES-TAP

The Weather Station receives satellite imagery from the Geostationary Operational Environment Satellite (GOES) and the Japanese Geostationary Meteorological Satellite (GMS) through the GOES-TAP system operated by the NOAA Satellite Field Station in Honolulu. The imagery are recorded on a high-resolution laser facsimile. The normal schedule of transmission includes infrared hemispheric imagery every three hours. GOES West is currently inoperable.

3.6.9 ALCOR and TRADEX Radars

ALCOR, operating at C-band, is the primary weather measurement radar with TRADEX (S-band) designated as back-up when weather data is requested. Radar cross-section (RCS) values measured by ALCOR during pre- and post-mission scans of nominal trajectories are averaged and transmitted at a rate of 10 Hz to the KCC where they are recorded in real-time on the KREMS RTP computer tape. Post-mission processing of RCS values is performed in the KCC using the Moist Program which calculates radar reflectivity. Using nominal parameters, estimates of cloud moisture content and weather sensitivity index are derived. See Section 3.2.1 for more information on ALCOR and TRADEX capabilities.

3.6.10 Radar Scan Converter and Color Display

Horizontal and vertical scans of the ALCOR radar are transmitted to the weather station and are contoured in 16 pre-selected colors representing areas of equal intensity. The intensity of signal return is used to infer drop-size spectra and mass of liquid water content.

3.6.11 Defense Meteorological Satellite Program (DMSP)

The DMSP receiver provides access to GMS, GOES, DMSP and NOAA satellite data. Display scales of 1:15 million or 2:7.5 million are selectable. Available processing techniques allow the product to be enhanced at different portions of the infrared spectrum to emphasize the cloud cover at selected altitudes.

3.6.12 Micromet System

The micromet system measures winds at remote locations and displays the data on site and at the weather station. The sensor are located on Roi-Namur and at Harbor Control on Kwajalein. The processing and display system consists of a minicomputer and printer at the weather station.

3.6.13 Tide Gauges

A bubbler-type, pressure recording tide gauge system provides a continuous strip chart recording of the tide height. The system works on the principle that pressure in a body of water varies with depth; therefore, with pressure sensors at a fixed level, the water level (tide) above the sensor is measured by observing the pressure at the sensor. The sensor is located off Echo Pier and the recorder is in the weather station.

A tide staff, graduated in tenths-of-a-foot and secure in a vertical position on a concrete pile at the pier, is read daily and is the standard of comparison for the other gauges.

3.6.14 Conventional Ground Measurements

Conventional meteorological instruments are used for wind, temperature, dew point, relative humidity, pressure, and precipitation. All these measurements are made at the weather station except for wind speed which is also measured at Omelek, Gellinam, Meck and Roi-Namur. Cloud height and ceiling data are collected but, due to lack of measuring equipment, they are visually estimated by the weather observer.

3.7 METRIC MEASUREMENTS

3.7.1 Tracking

3.7.1.1 Radar: Incoming and Outgoing

The tracking function can be broken into two categories: skin and beacon. Most of the radars on USAKA are intended for active tracking of targets by reflecting radio emissions off of their "skin" or surface. Some of the systems, however, are capable of tracking using a radio transmitter, or "beacon", located on the target. The skin tracking function can be further divided into subcategories distinguished by the type of targets being tracked: incoming (e.g. RV) and outgoing (e.g. locally launched missiles), and New Foreign Launch (NFL) and Deep Space (DS) targets. The following sections summarize the tracking capabilities of USAKA radars for these applications.

3.7.1.1.1 Skin Tracking. Most USAKA radars are designed to perform the skin tracking function. Capabilities for this function are summarized in Tables 3-1 to 3-8. The "Number of Targets" columns show how many targets each radar is capable of tracking. The Max Range numbers are given assuming a OdBsm target with a OdB SNR.

3.7.1.1.2 Beacon Tracking. There are three USAKA C-band radar systems currently capable of beacon tracking: ALCOR, FPQ-19, and MPS-36.

3.7.1.1.3 Radar: NFL and DS Tracking. New Foreign Launch (NFL) and Deep Space (DS) target tracking capabilities are primarily provided by the ALTAIR radar system. There are four different waveforms for use in these applications.

3.7.1.2 Optical Visible Resources

The principal metric measurements supported by the USAKA optical sensors are those related to trajectory reconstruction. Optimum trajectory coverage requires at least three tracking sensors per RV. Since there are six Super-RADOTs and only three RADOTs, the current range practice is to assign two Super-RADOTs and one RADOT to an RV. This implies that no more than three RVs can be optimally covered in any mission. In addition to permitting multilateration, redundant coverage by non-collocated sensors also precludes complete loss of data due to drifting clouds over any one sensor. This is a significant consideration given the prevailing USAKA cloud conditions.

Trajectory coverage by optical sensors is generally limited to within the atmosphere. Limited exoatmospheric tracking is possible with the Super-RADOTs, but only under specific conditions and times of day (i.e. sunlit RV observed during local nighttime). Although the optical sensors can collect data during the daytime, the much greater background (sky) illumination further reduces their effective range to well within the atmosphere. The current sensor resolutions should permit resolved imaging of an RV, at least in its later stages of flight. Such images might provide useful data on vehicle microdynamics

TABLE 3-1

ALTAIR (VHF) RADAR CAPABILITIES

CENTER FREQUENCY VHF 0.1620 GHz

FUNCTIONS

METRIC X SIGNATURE X OTHER ____

OUTPUT DATA

MAX. BANDWIDTH 7.06 MHz

PULSE LENGTHS 6, 30, 119, 238, 600 μsec.

POLARIZATION LC, RC (R); RC (T)

RCS ACCURACY Approx. 1 dB for elev. >5°

SNR @ 1000 KM. RANGE, OdBsm TGT 16-35 dB

VECTOR UPDATE RATE 10 Hz track filter

PRF 20, 60, 120, 372, 1724 Hz w/max. duty cycle of 1.2%

TRACKING ACCURACY

RANGE BIAS 4 m MISS DISTANCE: 79.5 m

ANGLE BIAS 200 μrad

RANGE PRECISION .005m (PDR)

ANGLE PRECISION 65 μrad.

RADAR/TARGET GEOMETRY

MAX. RANGE 3350 KM (T=OdBsm; SNR=10dB for V238)

MIN. RANGE 20 km (approx.)

MAX. ELEV. ANGLE 92°

MIN. ELEV. ANGLE 1°

TARGET COMPLEX

MAX. NO. OF TARGETS 32 (range; UHF + VHF)

3 dB BEAMWIDTH 48.9 mrad

CROSS RANGE WIDTH @ MAX RANGE 164 km

RANGE RESOLUTION (6 dB) 37.5 m RANGE WINDOW 19.3 km (at 372 PRF)

ANTENNA SLEWING RATES AZ 10°/sec EL 10°/sec

ANTENNA ACCELERATION RATES AZ <2°/sec² EL <5°/sec²

IMAGING YES____ NO X

RANGE RESOLUTION N/A

AZIMUTH RESOLUTION N/A

OTHER

ERIM

TABLE 3-2

ALTAIR (UHF) RADAR CAPABILITIES

CENTER FREQUENCY UHF 0.422 GHz

FUNCTIONS
METRIC X SIGNATURE X OTHER

OUTPUT DATA
MAX. BANDWIDTH 17.6 MHz
PULSE LENGTHS 0.1, 3, 120, 238, 400*, 1000* µsec (*space track only)
POLARIZATION LC, RC (R), RC (T)
RCS ACCURACY Approx. 1 dB for elev. >5°
SNR @ 1000 KM. RANGE, OdBsm TGT 17.4-46 dB
VECTOR UPDATE RATE 10 Hz track filter
PRF 50, 120, 210, 372, 1724 w/max. duty cycle of 5%

TRACKING ACCURACY
RANGE BIAS 4 m MISS DISTANCE: 79.5 m
ANGLE BIAS 200 µrad
RANGE PRECISION .005m (PDR)
ANGLE PRECISION 65 µrad
BEACON TRACK No

RADAR/TARGET GEOMETRY
MAX. RANGE 4870 km (T=OdBsm; SNR=10dB, U238)
MIN. RANGE 20 km (approx.)
MAX. ELEV. ANGLE 92°
MIN. ELEV. ANGLE 1°

TARGET COMPLEX
MAX. NO. OF TARGETS 32 (range; VHF + UHF)
3 dB BEAMWIDTH 19.2 mrad
CROSS RANGE WIDTH @ MAX RANGE 94 km
RANGE RESOLUTION (6 dB) 15 m RANGE WINDOW 19.3 km (at 372 PRF)
ANTENNA SLEWING RATES AZ 10°/sec EL 10°/sec
ANTENNA ACCELERATION RATES AZ <2°/sec^2 EL <5°/sec^2

IMAGING YES NO X
RANGE RESOLUTION
AZIMUTH RESOLUTION

OTHER

TABLE 3-3

TRADEX (L-BAND) RADAR CAPABILITIES

CENTER FREQUENCY L-BAND 1.320 GHz

FUNCTIONS
METRIC X SIGNATURE X OTHER ______

OUTPUT DATA
- MAX. BANDWIDTH 20 MHz
- PULSE LENGTHS 2.0, 50, 565 μsec.
- POLARIZATION RC LC (R); RC (T)
- RCS ACCURACY Approx. 1 dB for elev. >5°
- SNR @ 1000 KM. RANGE, OdBsm TGT 17-40 dB
- VECTOR UPDATE RATE 10 Hz track filter
- PRF 100-1500 Hz

TRACKING ACCURACY
- RANGE BIAS 1.6 m — MISS DISTANCE: 36.8 m
- ANGLE BIAS 105(az.), 65(el.) μrad
- RANGE PRECISION .003 m (PDR)
- ANGLE PRECISION 50(az.), 35(el.) μrad.
- BEACON TRACK No

RADAR/TARGET GEOMETRY
- MAX. RANGE 3162 km (T=OdBsm; SNR=10dB, LCHIRP)
- MIN. RANGE 20 km (approx.)
- MAX. ELEV. ANGLE 90°
- MIN. ELEV. ANGLE 0°

TARGET COMPLEX
- MAX. NO. OF TARGETS 1 (upgrade to 6 underway)
- 3 dB BEAMWIDTH 10.6 mrad
- CROSS RANGE WIDTH @ MAX RANGE 33.5 km
- RANGE RESOLUTION (6 dB) 15 m — RANGE WINDOW 2.58 km (LCHIRP)
- ANTENNA SLEWING RATES AZ 12.5°/sec EL 12.5°/sec
- ANTENNA ACCELERATION RATES AZ 13.2°/sec^2 EL 13.2°/sec^2

IMAGING YES ____ NO X
- RANGE RESOLUTION ______
- AZIMUTH RESOLUTION ______

OTHER
+3 dB improvement in SNR possible using Coherent Signal Processor. This can yield an increase in the maximum range by 18-19% for the same SNR.

ERIM

TABLE 3-4

TRADEX "MMS" (L-BAND) RADAR CAPABILITIES

CENTER FREQUENCY L-Band 1.320 GHz

FUNCTIONS

METRIC X SIGNATURE X OTHER

OUTPUT DATA

MAX. BANDWIDTH 20 MHz

PULSE LENGTHS 2, 50 μsec.

POLARIZATION LC (metric); RC, LC (signature)

RCS ACCURACY ± 2 dB

SNR @ 1000 KM. RANGE, OdBsm TGT 55.9 dB (120 km; Burst)

VECTOR UPDATE RATE Undefined

PRF 100-1500 (same as L-band)

TRACKING ACCURACY

RANGE BIAS 2.23 m MISS DISTANCE: N/A

ANGLE BIAS N/A

RANGE PRECISION .003 m (PDR)

ANGLE PRECISION N/A

BEACON TRACK No

RADAR/TARGET GEOMETRY

MAX. RANGE 1685 km (T=OdBsm; SNR=10dB, Burst)

MIN. RANGE 20 km (approx.)

MAX. ELEV. ANGLE N/A

MIN. ELEV. ANGLE N/A

TARGET COMPLEX

MAX. NO. OF TARGETS 1

3 dB BEAMWIDTH 45.4 mrad (each remote site)

CROSS RANGE WIDTH @ MAX RANGE 76 km

RANGE RESOLUTION (6 dB) 15 m RANGE WINDOW 1215 m (1500 PRF)

ANTENNA SLEWING RATES AZ 42°/sec (I) 72°/sec (G) EL 15°/sec (I) 28°/sec (G)

ANTENNA ACCELERATION RATES AZ 20°/sec (I) 55°/sec^2 (G) EL 15°/sec (I) 38°/sec^2 (G)

IMAGING YES NO X

RANGE RESOLUTION N/A

AZIMUTH RESOLUTION N/A

OTHER

TABLE 3-5

TRADEX (S-BAND) RADAR CAPABILITIES

CENTER FREQUENCY S-BAND 2.950 GHz

FUNCTIONS
METRIC X SIGNATURE X OTHER

OUTPUT DATA
MAX. BANDWIDTH 250 MHz (FJB)
PULSE LENGTHS 3, 9 μsec.
POLARIZATION RC, LC, 45°, 135° linear (R); RC, 45°, 135° linear (T)
RCS ACCURACY Undefined
SNR @ 1000 KM. RANGE, OdBsm TGT 23-27 dB
VECTOR UPDATE RATE N/A (range only)
PRF 750 Hz (pulse pair); 1500 (chirps)

TRACKING ACCURACY
RANGE BIAS 1.5m MISS DISTANCE: N/A (range only)
ANGLE BIAS N/A
RANGE PRECISION .003 m (PDR)
ANGLE PRECISION N/A
BEACON TRACK No

RADAR/TARGET GEOMETRY
MAX. RANGE 2661 km (T=OdBsm; SNR=10dB; NB Chirp)
MIN. RANGE 20 km (approx.)
MAX. ELEV. ANGLE 90°
MIN. ELEV. ANGLE 0°

TARGET COMPLEX
MAX. NO. OF TARGETS 1 (upgrade to 6 underway)
3 dB BEAMWIDTH 5.2 mrad
CROSS RANGE WIDTH @ MAX RANGE 13.8 km
RANGE RESOLUTION (6 dB) 5.5 m (WB) RANGE WINDOW 2816 m (WB 1500 PRF)
ANTENNA SLEWING RATES AZ 12.5°/sec EL 12.5°/sec
ANTENNA ACCELERATION RATES AZ 13.2°/sec^2 EL 13.2°/sec^2

IMAGING YES NO X
RANGE RESOLUTION N/A
AZIMUTH RESOLUTION N/A

OTHER
Range only tracking.

TABLE 3-6

ALCOR (C-BAND) RADAR CAPABILITIES

CENTER FREQUENCY C-BAND 5.67 GHz

FUNCTIONS
METRIC X SIGNATURE X OTHER

OUTPUT DATA
MAX. BANDWIDTH 512 MHZ WB
PULSE LENGTHS 10.2 μsec (NB), 10.0 μsec (WB)
POLARIZATION RC, LC (R); RC (T)
RCS ACCURACY Approx. 1 dB for Elev. > 10°
SNR @ 1000 KM. RANGE, OdBsm TGT 23 dB
VECTOR UPDATE RATE 10 Hz track filter
PRF 38-203 HZ (upgrade to 400 underway)

TRACKING ACCURACY
RANGE BIAS .4 m MISS DISTANCE: 61.8 m
ANGLE BIAS 110 μrad Az., 60 μrad El.
RANGE PRECISION .001 (PDR)
ANGLE PRECISION 135(az.), 140(el.) μrad
BEACON TRACK Yes

RADAR/TARGET GEOMETRY
MAX. RANGE 2113 km (T=OdBsm, SNR=10dB; for NB)
MIN. RANGE 12 km (approx.)
MAX. ELEV. ANGLE 95.8°
MIN. ELEV. ANGLE -3.2°

TARGET COMPLEX
MAX. NO. OF TARGETS 1 (upgrade to 2 in CSO planned)
3 dB BEAMWIDTH 5.2 mrad
CROSS RANGE WIDTH @ MAX RANGE 11 km
RANGE RESOLUTION (6 dB) .54 m WB RANGE WINDOW 2500 m (NB)
90 m (WB)
ANTENNA SLEWING RATES AZ 10°/sec EL 10°/sec
ANTENNA ACCELERATION RATES AZ $6°/sec^2$ EL $6°/sec^2$

IMAGING YES X NO
RANGE RESOLUTION .54 m
AZIMUTH RESOLUTION .54 m

OTHER
Cannot Support Lagoon Impact

Beacon range and angle bias and precision are smaller by a factor of approx. 3-4.

TABLE 3-7

FPQ-19 (C-BAND) RADAR CAPABILITIES

CENTER FREQUENCY C-BAND 5.650 GHz

FUNCTIONS
METRIC X SIGNATURE ____ OTHER ____

OUTPUT DATA
MAX. BANDWIDTH 4.8 MHz
PULSE LENGTHS 0.25, 0.50, 1.0, 5.0 μsec
POLARIZATION LC, linear V (T)
RCS ACCURACY Undefined
SNR @ 1000 KM. RANGE, OdBsm TGT 14.5 dB
VECTOR UPDATE RATE Undefined
PRF 160, 320, 640

TRACKING ACCURACY
RANGE BIAS 4.5 m (skin), 7.9 m (BCN) MISS DISTANCE: 28.4 m
ANGLE BIAS 10 μrad
RANGE PRECISION 7.6 m (skin), 5.2m (BCN)
ANGLE PRECISION 80(az.); 60(el.) μrad
BEACON TRACK Yes

RADAR/TARGET GEOMETRY
MAX. RANGE 1298 km (T=OdBsm: SNR=10dB)
MIN. RANGE Undefined
MAX. ELEV. ANGLE 89°
MIN. ELEV. ANGLE -1°

TARGET COMPLEX
MAX. NO. OF TARGETS 2
3 dB BEAMWIDTH 7 mrad
CROSS RANGE WIDTH @ MAX RANGE 9.1 km
RANGE RESOLUTION (6 dB) >31 m RANGE WINDOW Undefined
ANTENNA SLEWING RATES AZ 350 mils/sec EL 350 mils/sec
ANTENNA ACCELERATION RATES AZ 350 mils/sec^2 EL 350 mils/sec^2

IMAGING YES ____ NO X
RANGE RESOLUTION N/A
AZIMUTH RESOLUTION N/A

OTHER

TABLE 3-8

MPS-36 (C-BAND) RADAR CAPABILITIES

CENTER FREQUENCY C-BAND 5.650 GHz

FUNCTIONS
METRIC X SIGNATURE ____ OTHER ____

OUTPUT DATA

MAX. BANDWIDTH 4.8 MHz

PULSE LENGTHS 0.25, 0.50, 1.0 μsec

POLARIZATION LC, V, H

RCS ACCURACY Undefined

SNR @ 1000 KM. RANGE, OdBsm TGT -18.3 dB

VECTOR UPDATE RATE Undefined

PRF 160, 320, 640 Hz

TRACKING ACCURACY

RANGE BIAS 5.2 m MISS DISTANCE: 46.0 m

ANGLE BIAS 30(az.), 40(el.) μrad

RANGE PRECISION 4.2 m

ANGLE PRECISION 110(az.), 120(el.) μrad

BEACON TRACK Yes

RADAR/TARGET GEOMETRY

MAX. RANGE 196 km (T=OdBsm; SNR=10dB)

MIN. RANGE Undefined

MAX. ELEV. ANGLE 89^{0}

MIN. ELEV. ANGLE -0.5^{0}

TARGET COMPLEX

MAX. NO. OF TARGETS 1

3 dB BEAMWIDTH 2.09 mrad

CROSS RANGE WIDTH @ MAX RANGE 410 m

RANGE RESOLUTION (6 dB) >31 m RANGE WINDOW Undefined

ANTENNA SLEWING RATES AZ 1000 mr/sec EL 500 mr/sec

ANTENNA ACCELERATION RATES AZ 400 mr/sec^2 EL 400 mr/sec^2

IMAGING YES ____ NO X

RANGE RESOLUTION N/A

AZIMUTH RESOLUTION N/A

OTHER

(coning, nutation, etc.). However, the current sensor configurations result in the vehicles appearing as "blobs of light" due to saturation effects. Thus, the additional metric potential of RV imaging is not being realized.

3.7.2 Location Determination

The location determination function requires identifying the position of a target at the occurrence of a specific event. There are three potential categories for this function: (1) locating the "pierce-point" (i.e. the position where a target enters the atmosphere); (2) locating the "impact-point" (i.e. the position where a target impacts the ground or water); and (3) locating an intercept point between an interceptor and a target. The event is usually defined in terms of a specific altitude (e.g. 0 meters for impact and 300,000 feet for the pierce point) and may be made directly or from analysis of tracking information. Locations determined from tracking information are a function of radar tracking capabilities and can be determined using cross-range position accuracy.

Besides using radar trajectory to extrapolate impact position, USAKA has the HITS and SDRs to directly measure water impact positions.

3.7.3 Target Microdynamics

Besides measuring target trajectories, users often require information about the motion of a target relative to some point on the target (e.g. the nosetip of an RV). This motion data is referred to as target "microdynamics" where tracking information relates to target "macrodynamics". Several USAKA radars are capable of collecting this data through range-Doppler imaging.

3.8 SIGNATURE MEASUREMENTS

3.8.1 Amplitude Characteristics

3.8.1.1 Radar

USAKA range users are often interested in the radar cross section (RCS) characteristics of targets as measured from radar sites. The signatures may be characterized by a single measure (absolute) or relative measure between two or more measurement parameters. In this section, active signatures are broken into total RCS, differential RCS, and image or spatial RCS distribution.

3.8.1.1.1 Total RCS. Total RCS is considered to be the single RF signature value for a certain center frequency integrated over some bandwidth, usually narrowband.

3.8.1.1.2 Differential RCS. The amplitude of target RCS signatures as a function of frequency is defined here to be differential RCS. Usually, differential RCS measurements require wideband, or frequency stepped narrowband, signals.

3.8.1.1.3 Image or Spatial RCS. Image or spatial RCS is defined to be the target RCS amplitude as a function of position on the target. This requires a large transmit bandwidth for good range resolution and a large Doppler bandwidth for good cross range resolution.

3.8.1.2. Optical (Visible) Resources

The signature measurements supported by the current USAKA optical sensors include estimates of RV radiant intensity. Measurements are limited to roughly the visible spectrum between 380 and 690 nanometers. The radiant intensity estimates are made via photometric (i.e. photographic density measurement) techniques from the RADOT and Super-RADOT 70 mm film data. The conversion of film density to radiant intensity is based on calibration frames containing stars of known intensity.

Current limitations to radiance measurements include: 1) trajectory altitudes must be below 60,000 feet; 2) the use of photographic emulsions as the detection medium limits the dynamic range available often resulting in film saturation problems, and 3) the use of photometry to estimate radiance is a relatively inaccurate process often yielding results accurate only to within a factor of two.

3.8.2 Spectral Characteristics (Optical Resources)

The spectral analysis of RV radiant intensity is made with data collected by Spectral Ballistic Cameras (SBCs). The spectral band covered is from 380 to 690 nanometers with variable resolutions of 1.33, .8 and .4 nanometers. The SBC FOV is 681 x 681 mrad. Current limitations to spectral measurements include: 1) trajectory altitudes must be below 40,000 feet, and 2) the use of photographic emulsions as the detection medium limits the dynamic range available with film saturation being common.

3.9 SUPPORTING SERVICES

3.9.1 Telemetry

3.9.1.1 Tracking

The ground stations consist of eight autotracking antennas, one transportable autotrack antenna, one fixed position antenna and one re-transmission system. The current telemetry assets can provide for a maximum of nine separate trackable links. In terms of RV links, USAKA could track up to nine instrumented RVs (IRVs) which are at wide angular dispersion with no redundancy. Or, one telemetry antenna could be used to track one primary IRV and several additional IRVs if they were all spatially within the 3 dB beamwidth. However, most missions require backup tracking antennas and receives as a precaution and hence only four IRVs could realistically be tracked by the available number of TM antennas.

3.9.1.2 Receiving and Recording

USAKA range instruments are capable of receiving, recording and processing PCM/FM, PCM/FM/FM, PDM/FM/FM, PDM/FM, PAM/FM/PM, and PDM/FM/PM. TM channel capacity is limited to about 1.2Mbps for PCM/FM due to available bandwidth of the reception instruments. In addition, TM magnetic tape recorder bandwidths are limited to 1MHz for FM and 4MHz for direct.

In the most extreme case when nine IRVs are being tracked the maximum number of separate TM channel links from each IRV would be eight. This is based on the available number of multicouplers, data receivers and recorders. However, when redundancy of data acquisition is required (most missions), then the maximum number of IRVs to track and link cannot exceed four. This is based on providing two dedicated autotrack antennas for each IRV. In this case the available number of multicouplers, receivers and recorders do not impose any limitations.

3.9.2 AN/TPX-42A Radar

The TPX-42A is a X-band, beacon interrogation system which monitors normal air traffic in the USAKA area and vectors instrumentation aircraft in support of specific missions. The primary purpose of the system is to plot on a plan position indicator (PPI) not only the aircraft range and bearing, but also the altitude, aircraft identification code, and aircraft path. Also, provisions are provided for aural and visual indication of aircraft communication failure, emergency, and hijack replies. The system can maintain a maximum of 128 targets.

3.10 SPECIFIC RADAR CAPABILITIES

USAKA radar capabilities have been outlined in a format similar to that used for the user needs summarized in Section 2. Specific details are provided in Tables 3-1 through 3-11. Most capabilities shown in these tables were transferred from current documentation.[3,4] A few have been derived from other parameters provided in the reference documentation while update rate, miss distance, and maximum range calculations are described below.

3.10.1 Update Rate

The update rate can be no faster than the PRF rate but is normally slower because "n" samples are needed to calculate the desired output parameter to the required accuracy. Normally A 10 Hz tracking filter is used so that the vector data update rate is 10 Hz.

3.10.2 Miss Distance

Miss distance, 'n meters, has been calculated for an approximate pierce point range as a means of characterizing relative tracking performance between different radars. The relation used was:

$$\text{MISS DISTANCE} = \left\{ R_1^2 + \delta R_1^2 + R_0^2 \left[\left(A_B^2 + A_N^2 \right) + \left(E_B^2 + E_N^2 \right) \right] \right\}^{1/2} \qquad \ldots(3\text{-}1)$$

R_1 = range bias (meters)

δR_1 = range precision (meters) or noise

R_0 = 267,000 meters *

A_B = azimuth angle bias (radians)

A_N = azimuth angle noise (radians)

TABLE 3-9

SDR (X-BAND) RADAR CAPABILITIES

CENTER FREQUENCY X-BAND 9.375 GHz

FUNCTIONS

METRIC X SIGNATURE ____ OTHER ____

OUTPUT DATA

MAX. BANDWIDTH 9.6 MHZ

PULSE LENGTHS 0.125 μsec

POLARIZATION vertical

RCS ACCURACY N/A

SNR @ 1000 KM. RANGE, OdBsm TGT N/A

VECTOR UPDATE RATE N/A

PRF 1805, 3003, 3620

TRACKING ACCURACY

RANGE BIAS 9 m MISS DISTANCE: N/A

ANGLE BIAS 200 μrad

RANGE PRECISION 9 m

ANGLE PRECISION 0.38 mrad

BEACON TRACK No

RADAR/TARGET GEOMETRY

MAX. RANGE 30 km

MIN. RANGE 8 km

MAX. ELEV. ANGLE 2°

MIN. ELEV. ANGLE 0°

TARGET COMPLEX

MAX. NO. OF TARGETS N/A

3 dB BEAMWIDTH 10.4 mrad AZ 34.9 mrad EL

CROSS RANGE WIDTH @ MAX RANGE 312 m

RANGE RESOLUTION (6 dB) 9 m RANGE WINDOW N/A

ANTENNA SLEWING RATES AZ sweep EL N/A

ANTENNA ACCELERATION RATES AZ N/A EL N/A

IMAGING YES ____ NO X

RANGE RESOLUTION N/A

AZIMUTH RESOLUTION N/A

OTHER

TABLE 3-10

MMW (Ka-BAND) RADAR CAPABILITIES

CENTER FREQUENCY Ka-Band 35 GHz

FUNCTIONS
METRIC X SIGNATURE X OTHER

OUTPUT DATA

MAX. BANDWIDTH 1000 MHz

PULSE LENGTHS 50 μsec

POLARIZATION RC LC (R), RC (T)

RCS ACCURACY Undefined

SNR @ 1000 KM. RANGE, OdBsm TGT 17 dB

VECTOR UPDATE RATE 10 Hz track filter

PRF 50-2000 Hz

TRACKING ACCURACY

RANGE BIAS .9 m MISS DISTANCE: 16.4 m

ANGLE BIAS 35 μrad

RANGE PRECISION .001 m (PDR)

ANGLE PRECISION 30(az.), 20(el.) μrad

BEACON TRACK No

RADAR/TARGET GEOMETRY

MAX. RANGE 1496 km

MIN. RANGE 20 km (approx.)

MAX. ELEV. ANGLE 86°

MIN. ELEV. ANGLE -5°

TARGET COMPLEX

MAX. NO. OF TARGETS 1

3 dB BEAMWIDTH 760 μrad

CROSS RANGE WIDTH @ MAX RANGE 1137 m

RANGE RESOLUTION (6 dB) .28 m RANGE WINDOW 37.5 m(WB)

ANTENNA SLEWING RATES AZ 12°/sec EL 12°/sec

ANTENNA ACCELERATION RATES AZ 2°/sec^2 EL 2°/sec^2

IMAGING YES X NO

RANGE RESOLUTION .28 m

AZIMUTH RESOLUTION .28 m

OTHER
Cannot Support Lagoon Impacts

TABLE 3-11

MMW (W-BAND) RADAR CAPABILITIES

CENTER FREQUENCY W-Band 95.5 GHz

FUNCTIONS
METRIC X SIGNATURE X OTHER

OUTPUT DATA
- MAX. BANDWIDTH 1000 MHz
- PULSE LENGTHS 50 μSEC
- POLARIZATION RC LC (R), RC (T)
- RCS ACCURACY Undefined
- SNR @ 1000 KM. RANGE, OdBsm TGT -3 dB
- VECTOR UPDATE RATE N/A
- PRF Undefined

TRACKING ACCURACY
- RANGE BIAS Undefined MISS DISTANCE: N/A
- ANGLE BIAS Undefined
- RANGE PRECISION Undefined
- ANGLE PRECISION Undefined
- BEACON TRACK No

RADAR/TARGET GEOMETRY
- MAX. RANGE 473 km (T=OdBsm; SNR=10dB)
- MIN. RANGE 20 km (approx.)
- MAX. ELEV. ANGLE 86°
- MIN. ELEV. ANGLE -5°

TARGET COMPLEX
- MAX. NO. OF TARGETS 1
- 3 dB BEAMWIDTH 280 μrad
- CROSS RANGE WIDTH @ MAX RANGE 132 m
- RANGE RESOLUTION (6 dB) Undefined RANGE WINDOW 37.5 m
- ANTENNA SLEWING RATES AZ 12°/sec EL 12°/sec
- ANTENNA ACCELERATION RATES AZ $2°/sec^2$ EL $2°/sec^2$

IMAGING YES X NO
- RANGE RESOLUTION .28 m
- AZIMUTH RESOLUTION Undefined

OTHER
Cannot Support Lagoon Impact

E_B = elevation angle bias (radians)

E_N = elevation angle noise (radians)

* approximate range of pierce point at 20° elevation angle.

3.10.3 Maximum Range

Maximum range for the radar has been calculated using the SNR (sensitivity) value shown for the particular radar and waveform pulse length in the 1988 USAKA Facilities and Instrumentation Manual for a 0dBsm target at 1000 kilometer range via the following equation:

$$SNR = \alpha\gamma \frac{\sigma_T}{R^4} \qquad \text{...(3-2)}$$

where

γ = pulse length

σ_T = target RCS (0dBsm, here)

R = range

The value of "α" can be determined from the available data. The maximum range is then calculated for SNR = 10dB for minimum acceptable tracking performance. Maximum effective range for other SNR conditions or pulse lengths can also be calculated using equation (3-2).

3.11 TELEMETRY CAPABILITIES

Telemetry capabilities are summarized in Table 3-12.

3.12 OPTICAL CAPABILITIES

The capabilities of the ground-based USAKA optical sensors are summarized in Table 3-13. As discussed in Section 2.4, the majority of user needs in the optical regions involve sensors on airborne

Table 3-12
TELEMETRY CAPABILITIES

Data Reception Capabilities

Polarization - RC, LC

Data Rate - 1.0 Mbs

Data Encryption - Yes

Bandwidth - Standard IRIG S-Band (2.2-2.4 GHz) after upgrade is complete

Center Frequency - Any standard frequency required by user within the S-Band range of 2.2 to 2.3 GHz

Number Data Channels - Typically no more than 8 channel outputs per antenna receiver

Channel Data Output (Video) Bandwidth to Recorder - 1.5 MHz

Modulation - PCM/FM, PCM/FM/FM, PDM/FM/FM, PDM/FM, PAM/FM/PM

Data Recorders (Magnetic Tape) - 14 tracks per each recorder

Data Recorder Frequency Response - 4 MHz direct (1 MHz FM)

Tracking Capabilities

Antenna System	Five 3-Meter	One 3-Meter	One 5.5 Meter	One 7-Meter	One 9-Meter
Frequency	2.2-2.3	2.2-2.3	2.2-2.3	2.2-2.3	2.2-2.3
Gain (dB)	34.5	34.5	39.5	42	43.5
3 dB Beamwidth (deg)	3.2	3.2	1.8	1.3	1.1
Polarization (circ)	LH&RH	LH&RH	LH&RH	LH&RH	LH&RH
Tracking Dynamics					
Velocity (deg/sec)	20	15	15	15	15
Accel (deg/sec/sec)	5	10	3	10	10
Figure of Merit (dB)	9	7.6	15.5	17	18.5
P-Band Output (MHz)	215-315	215-315	215-315	215-315	215-315

Table 3-13. Summary of USAKA Optical Data Capabilities

Instrument	Metric Data (Elev. / Azim.)	Broad-Band Radiant Intensity	Spectral Radiant Intensity	Engineering Sequential Photography	Streak / Documentary Photography
Super-RADOT	Accuracy = 25 μrad Endo targets (Limited exo capability with proper illumination)	$\Delta\lambda = 0.4 - 0.7 \mu m$ Accuracy = 5-50% Max Alt.= 60 Kft	N/A	Frame rates up to 120/sec	Doc. Video FOV = 1.3°
RADOT	Accuracy = 55 μrad Endo targets only	$\Delta\lambda = 0.4 - 0.7 \mu m$ Accuracy = 5-50% Max Alt.= 60 Kft	N/A	Frame rates up to 2500/sec	Doc. Video FOV variable from 2-50°
Ballistic Camera (BC-4)	Accuracy = 65 μrad Endo targets only	N/A	N/A	N/A	Streak only FOV = 45°
Spectral Ballistic Camera	N/A	N/A	$\delta\lambda = 4, 8$ Å $\Delta\lambda = 0.4 - 0.7 \mu m$ Max Alt.= 40 Kft	N/A	N/A
Camera Towers/ Mobile Photo Systems	N/A	N/A	N/A	Frame rates up to 2500/sec	MOPIC Color Video 4 x 5 Stills

platforms. In the past, these needs have been addressed by flying aircraft equipped with one or more sensor systems during USAKA missions. While not considered range assets, these systems fall within the category of existing capabilities available to support USAKA missions. Thus, the capabilities of three such systems, namely, HALO (High Altitude Learjet Observatory), IRIS (Infra Red Instrumentation System) and ARGUS, are listed in Table 3-14 through 3-18.

Table 3-14

HALO ULTRAVIOLET CAPABILITIES

		Reentry Phase
Geometric		
Field of View	Acq	Field of Regard: 60°V x 50°H
	Track	0.71° x 0.94°
Angular Accuracy		175 μrad rel. to A/C
Elevation	Max	60°
	Min	0°
Slew Rate		8°/sec max. tracking rate 30°-60°/sec max. slew rate
Frame Rate		30 Hz
Radiometric		
Spectral Band (s)		0.32 - 0.39 μm
Range	Max	
	Min	
Illumination	Target	
	Sky	
App Temp		
Resolution		51 x 34 μrad
SNR		NEI = 1.E-20 w/cm^2
Dynamic Range		~50 dB
Platform Characteristics		
Altitude		45 kft
Time-on-Station		3-4 hours
Positional Accuracy		.05° roll, pitch; 0.5° heading
Com		

Table 3-15
HALO VISIBLE CAPABILITIES

		Late Midcourse Phase	Reentry Phase
Geometric			
Field of View	Acq	Field of Regard:	60°V x 50°H
	Track	11°V x 14.6°H; 5.5°V x 7.3°H; 0.45°V x 0.6°H	
Angular Accuracy			
Elevation	Max	60°	60°
	Min	0°	0°
Slew Rate			
Frame Rate		30 Hz	30 Hz
Radiometric			
Spectral Band (s)		---------0.42-0.65 μm----------	
Range	Max	Horizon Break	
	Min		
Illumination	Target		
	Sky		
App Temp			
Resolution		-------------35 μrad at NFOV----	
SNR			
Dynamic Range		~50 dB	~50 dB
Platform Characteristics			
Altitude		------------45 kft-------------	
Time-on-Station		----3-4 hours-------------------	
Positional Accuracy		---0.05° roll, pitch; 0.5° heading--	
Com			

Table 3-16

ARGUS VISIBLE CAPABILITY (Late Midcourse and Reentry Phases)

		High Res. Vis. Camera	Cast Glance	Wide Angle Camera	Ballistic Camera
Geometric					
Field of View	Acq	50°V x 50°H	55°V x 42°H	48°V x 49°H	50°V x 46°H
	Track	0.22°V x 0.28°H 0.36°V x 0.54°H	0.05°V x 0.06°H 0.27°V x 0.35°H 2.7-6°V x 3.6-8°H	7.3°V x 9.7°H	20° dia.
Angular Accuracy		10 mrad	10 mrad	10 mrad	10 mrad
Elevation	Max	55°	55°	48°	50°
	Min	5°	0°	0°	0°
Slew Rate		244 mrad/sec	105 mrad/sec	---	140 mrad/sec
Frame Rate		30 Hz (video)	30 Hz	30 Hz	N/A
Radiometric					
Spectral Band (s)		0.4-0.9 μm	0.4-0.9 μm	0.4-0.9 μm	0.4-0.9 μm
Range	Max				
	Min				
Illumination	Target				
	Sky				
App Temp					
Resolution		30 μrad	30 μrad	750 μrad	250 μrad
SNR (sensitivity)		>+9 SM	+3 to +8 SM	+8 SM	+9 SM
Dynamic Range					

Platform Characteristics

Altitude	max. = 42 kft NC-135A
Time-on-Station	3-4 hours
Positional Accuracy	463 meters/hr CEP
Com	

Table 3-17

IRIS SHORT- AND MID-WAVE IR CAPABILITIES

		Late Midcourse Phase	Reentry Phase
Geometric			
		Field of Regard = 95°V x 90°H	
Field of View	Acq	2.6° x 2.6°	2.6° x 2.6°
	Track	------1.1° (WFOV);	0.3° (NFOV)---
Angular Accuracy			
Elevation	Max	+55°	+55°
	Min	-40°	-40°
Slew Rate			
Frame Rate		25 Hz	25 Hz
Radiometric			
Spectral Band (s)		2 cameras, each adjustable w/in 2.0-5.5 μm	
Range	Max		
	Min		
Illumination	Target	Day	
	Sky		
App Temp			
Resolution		120 μrad (WFOV);	100 μrad (NFOV)
SNR (sensitivity)		NESI=2 x 10^{-11}	$W/cm^2/\mu m$
Dynamic Range		50 dB	50 dB
Platform Characteristics			
Altitude		40 kft--------------------	
Time-on-Station		3-4 hours------------------	
Positional Accuracy		.05° roll, pitch;	0.5° heading
Com			

Table 3-18

ARGUS SWIR & MWIR CAPABILITIES

		IR Imaging System	IR Spectrometer
Geometric			
Field of View	Acq	32°V x 32°H	30°V x 32°H
	Track	0.27°V x 0.35°H	0.4°V x 0.4°H
Angular Accuracy		10 mrad	10 mrad
Elevation	Max	40°	40°
	Min	8°	10°
Slew Rate			
Frame Rate		30 Hz	1 Hz
Radiometric			
Spectral Band (s)		1.1 - 5.5 μm	0.7 - 5.5 μm
Range	Max		
	Min		
Illumination	Target	Day (Late Midcourse)	Day (Late Midcourse)
	Sky		
App Temp			
Resolution		100 μrad	----
SNR (sensitivity)		NEI = 4×10^{-8} W/cm^2 NETD = 0.08°C	----
Dynamic Range		60 dB	
Platform Characteristics			
Altitude		42 kft NC-135A	
Time-on-Station		3-4 hours	
Positional Accuracy		463 meters/hr CEP	
Com			

4.0 SHORTFALLS

Shortfalls or deficiencies in current capabilities have been determined by comparing the user needs, summarized in Section 2, with the USAKA capabilities defined in Section 3. A shortfall summary table outlines each sensor or equipment capability relative to user needs. These summaries are provided in Tables 4-1 through 4-15. Identified shortfalls are labelled with an asterisks (*). Shortfalls are categorized as: SF-1 (major); SF-2 (intermediate); or SF-3 (minor). In a number of cases, the available data, either on user needs or capabilities, suggests that definition of a shortfall can not be made and that further information or a clarification is needed. These are labelled TBR. Where no shortfall exists, categories are labelled as (OK).

Major shortfalls (SF-1) represent clear and significant lack of capability with respect to stated user needs. Establishment of a capability to meet major shortfalls will require substantial investment and time. Intermediate shortfalls (SF-2) represent definitive shortfalls which USAKA should attempt to resolve but which can likely be accomplished by modification of existing equipment or software. Minor shortfalls (SF-3) represent minor differences between stated user needs and current capabilities. It is recommended that these shortfalls not be fixed unless users can validate the need for the incremental advantages which would be offered by these minor improvements in capability.

4.1 RADAR SYSTEMS

Tables 4-1 through 4-7 summarize the user needs that are satisfied and those which indicate a capability shortfall in the following bands: VHF; UHF; L band; S band; C band; X band; and K_a band. (Note: No shortfall summary table is given for W band [i.e., 95 GHz] because no user needs were reported for that band.)

TABLE 4-1

SHORTFALL SUMMARY

RADAR

BAND VHF **CTR. FREQ.** 0.1620 GHz

LEGEND
*: identified shortfall
SF-1: major shortfalls (0)
SF-2: intermediate shortfalls (3)
SF-3: minor shortfalls (4)
OK: no shortfall
TBR: to be resolved (4)

FUNCTIONS Metric and Signature (OK)

OUTPUT DATA

Max. Bandwidth - (OK)

* Pulse Lengths - 0.25 μsec pulse length needed for RV tracking but not available (SF-2)

Polarization - no specific user requirement (TBR)

RCS Accuracy - (OK)

Min. SNR @ 1000 km - 31 dB is user need; this capability available but only for pulse lengths of 238 μsec or longer (OK) but see also Min. RCS below.

* Vector Update Rate - 20 Hz update rate requested only by USASDC; current capability is 10 Hz (SF-2)

* PRF - user high PRF needs (2976) are above current limit of 1724 Hz (SF-2)

TRACKING ACCURACY

* Range Bias - user needs 1.5 m; capability is 4.0 m (SF-3)

Angle Bias - (OK)

Range Precision - (OK)

Angle Precision - (OK)

Miss Distance - capability is 79.5 m; no quantitative user need (TBR)

Beacon Track - (OK)

TABLE 4-1 (Cont'd)

RADAR/TARGET GEOMETRY

* Max. Range - user need (4000 km) in excess of capability (3350 km) for SNR=10dB (SF-3); USSPACECOM desires 19,C00 km which exceeds even the capability of waveform V600N (TBR)

* Min. Range - user need (15 km) slightly smaller than capability (20 km) (SF-3)

Max. Elev. angle - (OK)

Min. Elev. angle - (OK)

TARGET COMPLEX

Max. No. of targets - (OK)

Min. RCS - user requirement (-25 dBsm/USSPACECOM and USASDC) inconsistent with maximum range and SNR requirements; (TBR)

* Max. complex dimensions - User beamwidth needed (3°) slightly larger than that available (2.8°) (SF-3)

Min. target separation - separation requirements (100 m) accommodated by range resolution (37.5 m); angle precision sufficient for angle separation (OK)

Maneuvering target - application dependent (OK)

IMAGING

Need/Capability (Y/N) - None

Range resolution - N/A

Azimuth resolution - N/A

OTHER COMMENTS

Simultaneous VHF and UHF already exists (OK).

TABLE 4-2

SHORTFALL SUMMARY

RADAR

BAND UHF **CTR. FREQ.** 0.4220 GHz

FUNCTIONS Metric and Signature - (OK)

LEGEND
*: identified shortfall
SF-1: major shortfalls (0)
SF-2: intermediate shortfalls (3)
SF-3: minor shortfalls (3)
OK: no shortfall
TBR: to be resolved (4)

OUTPUT DATA

* Max. Bandwidth - 18 MHz need, 17.6 MHz available (SF-3)
* Pulse Lengths - several additional pulse lengths needed - .1, 15, 40, 200 μsec. (SF-2)

Polarization - no specific user requirement - - (TBR)

RCS Accuracy - (OK)

Min. SNR @ 1000 km - (OK)

* Vector Update Rate - Same comment as VHF (SF-2)
* PRF - Same comment as VHF (SF-2)

TRACKING ACCURACY

* Range Bias - User needs 2.0m; capability is 4.0m (SF-3)

Angle Bias - (OK)

Range Precision - (OK)

Angle Precision - (OK)

Miss Distance - Same comment as VHF (TBR)

Beacon Track - (OK)

TABLE 4-2 (cont'd)

RADAR/TARGET GEOMETRY

Max. Range - user need satisfied (OK); USSPACECOM desires 19,000 km which exceeds even the capabilities of waveform U1000. (TBR)

* Min. Range - Same comment as VHF (SF-3)

Max. Elev. angle - (OK)

Min. Elev. angle - (OK)

TARGET COMPLEX

Max. no. of targets - (OK)

Min. RCS - same comment as VHF (TBR)

Max. complex dimensions - (OK)

Min. target separation - separation requirement (100 m) accommodated by range resolution (15 m); angle precision sufficient for angle separation (OK)

Maneuvering target - application dependent (OK)

IMAGING

Need/Capability (Y/N) - None

Range resolution - N/A

Azimuth resolution - N/A

OTHER COMMENTS

Simultaneous UHF and VHF already exists (OK)

TABLE 4-3

SHORTFALL SUMMARY

RADAR

BAND L CTR. FREQ. 1.320 GHz

FUNCTIONS Metric and Signature - (OK)

Legend
*: identified shortfall
SF-1: major shortfalls (0)
SF-2: intermediate shortfalls (1)
SF-3: minor shortfalls (1)
OK: no shortfall
TBR: to be resolved (3)

OUTPUT DATA

* Max. Bandwidth - User needs (285 MHz and 1400 MHz) far exceeds capability (20 MHz)--(SF-2)

Pulse Lengths - (OK)

Polarization - no specific user requirement (TBR)

RCS Accuracy - (OK)

Min. SNR @ 1000 km - (OK)

Vector Update Rate - (OK)

PRF - (OK)

TRACKING ACCURACY

Range Bias - (OK)

Angle Bias - Elevation (OK); azimuth need (80 μrad) less than capability (105 μrad) -- (TBR)

Range Precision - (OK)

Angle Precision - (OK)

Miss Distance - Capability 1.7m; no quantitative user need (TBR)

Beacon Track - (OK)

TABLE 4-3 (cont'd)

RADAR/TARGET GEOMETRY

Max. Range - (OK)

* Min. Range - User need (15 km) slightly smaller than capability (20 km) (SF-3)

Max. Elev. angle - (OK)

Min. Elev. angle - (OK)

TARGET COMPLEX

Max. No. of targets - needed (6); capability (1); Upgrade underway (OK)

Min. RCS - No user need (TBR)

Max. complex dimensions - (OK)

Min. target separation - (OK)

Maneuvering target - (OK)

IMAGING

Need/Capability (Y/N) - None

Range resolution - N/A

Azimuth resolution - N/A

OTHER COMMENTS

MMS provides no additional capability to address any of the identified shortfalls.

TABLE 4-4

SHORTFALL SUMMARY

RADAR

BAND S CTR. FREQ. 2.950 GHz

FUNCTIONS (Metric, Signature, Other)
S-band passive RF need from NASA is not available (TBR)

LEGEND
*: identified shortfall
SF-1: major shortfall (0)
SF-2: intermediate shortfall (3)
SF-3: minor shortfalls (1)
OK: no shortfall
TBR: to be resolved (6)

OUTPUT DATA

Max. Bandwidth - (OK)

Pulse Lengths - (OK)

Polarization - no specific user requirement (TBR)

RCS Accuracy - +/- 1 dB needed; current accuracy undefined (TBR)

Min. SNR @ 1000 km - user requirement of 27 dB is met by NB chirp and pulse pair waveforms (OK)

* Vector Update Rate - 20 Hz requested by USASDC; capability is 10 Hz (SF-2)

* PRF - lower limit needed (100 Hz) is considerably less than lower limit available (750 Hz) -- (SF-2)

TRACKING ACCURACY

Range Bias - (OK)

Angle Bias - N/A (range track only)

Range Precision - (OK)

Angle Precision - N/A (range track only)

Miss Distance - User expressed need; range only capability (TBR)

Beacon Track - (OK)

TABLE 4-4 (cont'd)

RADAR/TARGET GEOMETRY

* Max. Range - User need (4000 km) exceeds capability (2661 km) - (SF-2)
* Min. Range - Same comment as VHF (SF-3)

Max. Elev. angle - (OK)

Min. Elev. - (OK)

TARGET COMPLEX

Max. No. of targets - need (6); capability (1); upgrade underway (OK)

Min. RCS - Same comment as VHF (TBR)

Max. complex dimensions - (OK)

Min. target separation - (OK)

Maneuvering target - Range capability only (TBR)

IMAGING

Need/Capability (Y/N) - None

Range resolution - N/A

Azimuth resolution - N/A

OTHER COMMENTS

TABLE 4-5

SHORTFALL SUMMARY

RADAR

BAND C CTR. FREQ. 5.67 GHz

LEGEND
*: identified shortfall
SF-1: major shortfalls (0)
SF-2: intermediate shortfalls (3)
SF-3: minor shortfalls (4)
OK: no shortfall
TBR: to be resolved (4)

FUNCTIONS (Metric, Signature, Other)
(OK) - includes beacon tracking capability.

OUTPUT DATA

Max. Bandwidth - (OK)

Pulse Lengths - (OK)

Polarization - no specific requirement (TBR)

RCS Accuracy - (OK) - except in heavy weather (TBR)

Min. SNR @ 1000 km - user requirement of 23 dB is met by both NB and WB waveforms of ALCOR (OK)

* Vector Update Rate - 20 Hz requested by USASDC; capability is 10 Hz (SF-2)

* PRF - capability 38-203 Hz; user needs 10-400; 400 PRF upgrade in progress (SF-3)

TRACKING ACCURACY

Range Bias - (OK)

* Angle Bias - ALCOR azimuth bias (110 μrad) does not meet need (59 μrad) (SF-3)

Range Precision - (OK)

Angle Precision - (OK)

Miss Distance - capability .6 m; no quantitative user need (TBR)

Beacon Track - (OK)

TABLE 4-5 (cont'd)

RADAR/TARGET GEOMETRY

* Max. Range - user need (3000 km) exceeds capability (2113 km) - (SF-3)

* Min. Range - Same comment as VHF (SF-3)

Max. Elev. angle - (OK)

Min. Elev. angle - (OK)

TARGET COMPLEX

* Max. No. of targets - need (3); capability (1); upgrading to 2 - (SF-2)

Min. RCS - user requirement (-38 dBsm/USSPACECOM) inconsistent with maximum range and SNR requirements; (TBR)

* Max. complex dimensions - beamwidth need (3°) is ten times available capabilities (SF-2)

Min. target separation - (OK)

Maneuvering target - (OK)

IMAGING

Need/Capability (Y/N) - Yes

Range resolution - (OK)

Azimuth resolution - (OK)

OTHER COMMENTS

FPS-19 provides improved near range capability for max. complex dimensions but still does not meet need.

TABLE 4-6

SHORTFALL SUMMARY

RADAR

BAND X CTR. FREQ. 8-12 GHz

* FUNCTIONS (Metric, Signature, Other)
(SF-1) - no tracking or signature capability exists; SDR is only X-band radar.

LEGEND
*: identified shortfall
SF-1: major shortfalls (1)
SF-2: intermediate shortfalls (N/A)
SF-3: minor shortfalls (N/A)
OK: no shortfall
TBR: to be resolved (1)

OUTPUT DATA

Max. Bandwidth - no specific needs defined

Pulse Lengths - no specific needs defined

Polarization - no specific needs defined

RCS Accuracy - no specific needs defined

Min. SNR @ 1000 km - no specific needs defined

Vector Update Rate - need 20 Hz; no capability exists

PRF - need 1000 Hz; no capability exists

TRACKING ACCURACY

Range Bias - 1.5 m needed; no capability

Angle Bias - 100 μrad needed; no capability

Range Precision - .001 m needed; no capability

Angle Precision - 100 μrad needed; no capability

Miss Distance - splash only capability

Beacon Track - needed; no capability

TABLE 4-6 (cont'd)

RADAR/TARGET GEOMETRY

Max. Range - need 300 km; no capability exists

Min. Range - need 15 km; no capability exists

Max. Elev. angle - 90° needed; no capability

Min. Elev. angle - 0° needed; no capability

TARGET COMPLEX

Max. no. of targets - needed (2); no capability

Min. RCS - -38dBsm needed (range and SNR undefined)

Max. complex dimensions - no capability

Min. target separation - need 5m; no capability

Maneuvering target - needed but no details

IMAGING

Need/Capability (Y/N) - Yes, needed; no capability

Range resolution - .25 m needed; no capability

Azimuth resolution - .25 m needed; no capability

OTHER COMMENTS

Simultaneous imaging of 2 or more objects needed; no capability

Passive X-band needed by NASA but not available (TBR)

TABLE 4-7

SHORTFALL SUMMARY

RADAR

BAND K_a CTR. FREQ. 35 GHz

FUNCTIONS Metric and Signature (OK)

Legend

*: identified shortfall
SF-1: major shortfalls (0)
SF-2: intermediate shortfalls (3)
SF-3: minor shortfalls (2)
OK: no shortfall
TBR: to be resolved (8)

OUTPUT DATA

* * Max. Bandwidth - (OK); A 2 GHz bandwidth is desired by a variety of users (TBR)

Pulse Lengths - (OK)

Polarization - no specific user requirement (TBR)

* * RCS Accuracy - need 2 dB; capability undefined (SF-2)

Min. SNR @ 1000 km - need 25 dB; current capability is 17dB; upgrade underway (OK)

* * Vector Update Rate - need is 20 Hz; capability is 10 Hz (SF-2)

PRF - (OK)

TRACKING ACCURACY

Range Bias - (OK)

Angle Bias - (OK)

Range Precision - (OK)

Angle Precision - (OK)

Miss Distance - capability is .9 m; need is called for by users (TBR)

Beacon Track - (OK)

TABLE 4-7 (cont'd)

RADAR/TARGET GEOMETRY

Max. Range - need (3000 km); capability (1496 km); upgrade underway may not meet need (TBR); 19,000 km need expressed by USSPACECOM (TBR)

* Min. Range - Same comment as VHF (SF-3)

* Max. Elev. angle - max. needed (90°); capability (86°) -- (SF-3)

Min. Elev. angle - (OK)

TARGET COMPLEX

Max. No. of targets - (OK)

Min RCS - user requirement (-38 dBsm/USSPACECOM) inconsistent with maximum range and SNR requirements; (TBR)

* Max. complex dimensions - needed beamwidth is approximately 10 times capability (SF-2)

Min. target separation - (OK)

Maneuvering target - no specific need (TBR)

IMAGING

Need/Capability (Y/N) - Yes

Range resolution - (OK)

Azimuth resolution - (OK)

OTHER COMMENTS

USSPACECOM seeks greater availability of imaging radars (TBR)

4.2 TELEMETRY SYSTEMS

The determination of the shortfalls for telemetry at USAKA was interpreted by comparing user needs of Table 2-15 with the USAKA Telemetry Capabilities of Table 3-12. The results of this comparison are summarized in tabular form in Table 4-8. The current user requirements appeared to be fully satisfied by the existing capabilities at USAKA. However, there are future user programs which will certainly exceed the USAKA's existing capabilities. Specifically, future programs will require greatly increased data bit rates up to 20 Mbps. These programs would also require multiple data channel links with the instrumented vehicle. In addition, the number of instrumented vehicles which will require simultaneous, independent telemetry tracking is expected to increase which, in turn, would require additional antenna system capabilities at USAKA. Accordingly, the two most significant shortfalls seen for the future needs at USAKA are in the reception and recording of higher data rates, and the ability to track more instrumented vehicles which could be CONUS launched reentry vehicles or USAKA launched interceptors.

4.3 OPTICAL SYSTEMS

Tables 4-9 through 4-13 contain the shortfall summaries for the UV (below 0.4 micrometers), visible (0.4-0.7 μm), and SWIR/MWIR (0.7-5.0 μm) spectral regions. Shortfalls are designated by a solid box drawn around the relevant user need and corresponding sensor capability. Each box is labelled with the appropriate shortfall code. Because all the quantitative user needs of Section 2.4 are specified for airborne optical sensors, the optical shortfalls are defined with respect to the HALO, IRIS and ARGUS sensor capabilities that were given in Section 3.12. Note that because none of these systems has any LWIR (5-13 μm) or LLWIR (13-24 μm) capability, there are no shortfall tables for these regions. However, this lack of capability is itself a major shortfall. The Optical Airborne Measurement Program

Table 4-8
SHORTFALL SUMMARY
TELEMETRY

Data Reception Capabilities

Polarization - (OK)
Data Rate - need up to 20 Mbps, (SF-2)
Telemetry Bandwidth - Standard IRIG S-Band (OK)
Center Freq - (OK)
Number of Data Channels per Antenna System - (OK)
Output Data Channel (Video) Bandwidth to Recorder - Needs up to 60 MHz to accommodate a data rate up to 20 Mbps (SF-2)
Data Recorders (Magnetic Tapes) - 14 Channel (OK)
Data Recorder Frequency Response - Needs up to 60 MHz (SF-2)
Modulation Modes - (OK)
Encryption - (OK)

Antenna Systems and Tracking Capabilities

Frequency - (OK)
Gain - (OK)
Beamwidth - (OK)
Polarization - (OK)
Tracking Dynamics - (OK) for most users, may need future improvement for USAKA launched vehicles (TBR)
Figure of Merit - (OK)
Number of Antenna Systems - (OK) for most users, may need future additional antennas for tracking more instrumented reentry and USAKA launched vehicles (TBR)

Table 4-9

SHORTFALL SUMMARY

ULTRA-VIOLET REGION (below 0.4 μm) - Reentry Phase Only

Geometric		Req		HALO
Field of View (mrads)	Acq	---		1047 V x 873 H
	Track	---		12 x 16
Angular Accuracy (μrads)		---		---
Elevation (degrees)	Max	---		60
	Min	---		0
Slew Rate (mrad/s)		≥250	SF2	140
Frame Rate (Hz)		≤200 Hz	SF2	30 Hz

Note: Only USN/SSN has requirements

Table 4-9 (con't)

SHORTFALL SUMMARY

ULTRA-VIOLET REGION (below 0.4 μm) - Reentry Phase Only

Radiometric		Req	HALO
Spectral Band(s) (μmeters)		0.2-0.4 μm NB Capability	0.2-0.5 μm NB Capability
Range (km)	Max	300**	--------
	Min	15	--------
Illumination (Day/Night)	Target	D/N*	--------
	Sky	D/N*	--------
Size (m^2)		--------	--------
Emissivity		~0 to 1	--------
App Temp (°K)		--------	--------
Resolution (meters)		2 at lower alt.	0.5-11
SNR (dB)		20 dB TBR	NEI=1.E-20 w/cm^2
Dynamic Range		10^6* TBR	50 dB

* ERIM Interpretation

**ERIM Supplied

Table 4-10
SHORTFALL SUMMARY
HALO VISIBLE REGION (0.4 - 0.7 μm)

Geometric

		Req	HALO
Field of View (mrads)	Acq	10	1047 V x 873 H
	Track	.5	192 x 255 96 x 127 8 x 10
Angular Accuracy (μrads)		----	----
Elevation (degrees)	Max	----	60
	Min	----	0
Slew Rate (mrad/sec)		70** (LM) ≥250 (RE) SF2	140
Frame Rate (Hz)		10-30 Hz ≤200 Hz	30 video 200 film

*ERIM Interpretation **ERIM Supplied LM=Late Midcourse RE=Reentry

Table 4-10 (con't)
SHORTFALL SUMMARY
HALO VISIBLE REGION (0.4 - 0.7 μm)

Radiometric		Req	HALO	
Spectral Band(s) (μmeters)		0.4-0.7	.42-.65	SF3
Range (km)	Max	4000 (ST) 1000 (LM) 300** (RE)	------	TBR
	Min	200** (LM) 15 (RE)	------	
Illumination (Day/Night)	Target	D** (LM) D/N* (RE)	D** (LM) ---- (RE)	
	Sky	N** (LM) D/N** (RE)	N** (LM) ---- (RE)	
Size (m^2)		0.5	------	
Emissivity		~0 to 1	------	
App Temp (°K)		NA*	------	
Resolution (meters)		100 (ST) 300-2100 (LM) 2 (RE)	140 (ST) 7-35 (LM) 0.5-11 (RE)	SF3
SNR (dB)		≥10 dB	-------	
Dynamic Range		10^6*	50 dB	TBR

* ERIM Interpretation **ERIM Supplied LM=Late Midcourse RE=Reentry ST=Space Tracking

Table 4-11
SHORTFALL SUMMARY
ARGUS VISIBLE REGION (0.4-0.7 micrometers)

Geometric		NEED	ARGUS			
			High Resolution Visible Camera WF	High Resolution Visible Camera NF	Wide Angle	Ballistic Camera
Field of View (millirads)	Acq	10.0	873 V x 873 H		838 V x 855 H	873 V x 803 H
	Track	0.5	6Vx9H	4Vx5H	127 V x 169 H	350 dia.
Angular Accuracy (microrads)		----	---10,000--- TBR			
Elevation (degrees)	Max	----	55	55	48	50
	Min	----	5	5	0	0
Slew Rate (mrad/sec)		70** (LM) ≥250 (RE)	244	244 SF3	244	140
Frame Rate (Hz)		10 to 30 video ≤200 film	30 video 180 film	30 video 180 film SF3	30	N/A

**ERIM Supplied LM=Late Midcourse RE=Reentry

Table 4-11 (con't)
SHORTFALL SUMMARY
ARGUS VISIBLE REGION (0.4-0.7 micrometers)

Radiometric		NEED	ARGUS High Resolution Visible WF Camera NF	ARGUS Wide Angle	ARGUS Ballistic Camera
Spectral Bands (micrometers)		0.4-0.7	Video ICID	LLLTV	h.gh Speed Film
Range (kilometers)	Max	4000 (ST) 1000* (LM) 300** (RE)	-----TBR-----	-----TBR-----	-----TBR-----
	Min	200** (LM) 15** (RE)	-----	-----	-----
Illumination (Day/Night)	Target	D** (LM) D/N** (RE)	-----D** (LM) -----D/N** (RE)	-----D** (LM) -----D/N** (RE)	-----D** (LM) -----D/N** (RE)
	Sky	N** (LM) D/N** (RE)	-----N** (LM) -----D/N** (RE)	-----N** (LM) -----D/N** (RE)	-----N** (LM) -----D/N** (RE)
Size (meter^2)		N/A	-----	-----	-----
Emissivity		~0 to 1	-----	-----	-----
App Temp (K)		N/A	-----	-----	-----
Resolution (meters)		100 (ST) 300-2100 (LM) 2 (RE)	120 (ST) 6-30 (LM) 0.5-9 (RE) SF3	3000 (ST) 150-750 (LM) 11-225 (RE)	1000 (ST) 50-250 (LM) 4-75 (RE)
SNR (dB)		10	TBR Film-N/A Video->+9 Mag.	TBR +8 SM	TBR +9 SM
Dynamic Range		10^6*	-----TBR-----	-----TBR-----	-----TBR-----

*ERIM Interpretation **ERIM Supplied ST=Space Tracking LM=Late Midcourse RE=Reentry

Table 4-11 (con't)
SHORTFALL SUMMARY
ARGUS VISIBLE REGION (0.4-0.7 micrometers)

Geometric		NEED	ARGUS — Cast Glance Camera System (40", 60", 120" F.L. also available) 90-200 MM F.L.	80" F.L.	480" F.L.
Field of View (millirads)	Acq	10.0	----------960 V x 733 H----------		
	Track	0.5	47-105V x 63-140 H	5 V x 6 H	0.9 V x 1 H
Angular Accuracy (microrads)		----	----------10,000---------- TBR		
Elevation (degrees)	Max	----	----------55----------		
	Min	----	----------0----------		
Slew Rate (mrad/sec)		70** (LM) ≥250 (RE)	----------105---------- SF2		
Frame Rate (Hz)		≥10 to 30 video	30 video		

**ERIM Supplied LM=Late Midcourse RE=Reentry

Table 4-11 (con't)
SHORTFALL SUMMARY
ARGUS VISIBLE REGION (0.4-0.7 micrometers)

Radiometric		NEED	ARGUS — Cast Glance Camera System: 90-200 MM F.L. Video SIT	80" F.L. Video ICID	480" F.L. Video ICID
Spectral Bands (micrometers)		0.4-0.7			
Range (kilometers)	Max	4000 (ST) 1000* (LM) 300** (RE)	----------	----------TBR----------	----------
	Min	200** (LM) 15** (RE)	---------- ----------	---------- ----------	---------- ----------
Illumination (Day/Night)	Target	D** (LM) D/N** (RE)	---------- ----------	----------D**---------- ----------D/N**----------	----------(LM) ----------(RE)
	Sky	N** (LM) D/N** (RE)	---------- ----------	----------N**---------- ----------D/N**----------	----------(LM) ----------(RE)
Size (meter^2)		N/A	----------	----------	----------
Emissivity		~0 to 1	----------	----------	----------
App Temp (K)		N/A	----------	----------N/A----------	----------
Resolution (meters)		100 (ST) 300-2100 (LM) 2 (RE)	3000 (ST) 150-750 (LM) 11-230 (RE)	300 (ST) 15-75 (LM) 1.1-23 (RE)	160 (ST) 8-40 (LM) 0.6-12 (RE)
SNR (dB)		10	+8 SM	+5 SM	+3 SM
Dynamic Range		10^6*	----------	----------TBR----------	----------

*ERIM Interpretation **ERIM Supplied ST=Space Tracking LM=Late Midcourse RE=Reentry

Table 4-12
SHORTFALL SUMMARY
IRIS SHORT- AND MID-WAVE INFRARED REGION (0.7-3.0 AND 3.0-5.0 micrometers)

Geometric Phase		Req	IRIS
Field of View (mrads)	Acq	10	45 V x 45 H
	Track	.5	12 V x 15 H 3 V x 4 H
Angular Accuracy (μrads)		----	----
Elevation (degrees)	Max	----	55
	Min	----	-40
Slew Rate (mrad/sec)		70** (LM) ≥250 (RE)	140
		SF2	
Frame Rate (Hz)		10-30	25
		SF3	

**ERIM Supplied   LM=Late Midcourse   RE=Reentry

Table 4-12 (con't)
SHORTFALL SUMMARY
IRIS SHORT- AND MID-WAVE INFRARED REGION (0.7-3.0 AND 3.0-5.0 micrometers)

Radiometric		Req		IRIS
Spectral Band(s) (μmeters)		0.7-1.1 1.4-2.5 2.9-3.8 NB 2-5 0.7-5.0	SF1	2.0-5.5 adjustable
Range (km)	Max	1000* (LM) 300** (RE)	TBR	-----
	Min	200** (LM) 15 (RE)		-----
Illumination (Day/Night)	Target	D** (LM) D/N* (RE)		D** (LM) ---- (RE)
	Sky	N** (LM) D/N** (RE)		N** (LM) ---- (RE)
Size (m^2)		0.5		-----
Emissivity		~0 to 1		-----
App Temp (°K)		-----		-----
Resolution (meters)		300-2100 (LM) 2 (RE)		20-100 (LM) 1.5-30 (RE)
SNR (dB)		20 dB	TBR	NESI=2.E-11 w/cm^2/μm
Dynamic Range		10^6*	TBR	50 dB

* ERIM Interpretation **ERIM Supplied LM=Late Midcourse RE=Reentry

Table 4-13
SHORTFALL SUMMARY
ARGUS SHORT- AND MID-WAVE INFRARED REGION (0.7-3.0 AND 3.0-5.0 micrometers)

Geometric		NEED	ARGUS IR Spectrometer	ARGUS IR Imaging System
Frame Rate (Hz)				
Field of View (millirads)	Acq	10.0	524 V x 559 H	559 V x 559 H
	Track	0.5	7 x 7	4.7 V x 6.1 H
Angular Accuracy (microrads)		----	10,000 TBR	
Elevation (degrees)	Max	----	40°	
	Min	----	10°	
Slew Rate (mrad/sec)		70** (LM) ≥250 (RE)	TBR	
Frame Rate (Hz)		≥10 to 30	1 SF2	30

**ERIM Supplied LM=Late Midcourse RE=Reentry

Table 4-13 (con't)
SHORTFALL SUMMARY
ARGUS SHORT- AND MID-WAVE INFRARED REGION (0.7-3.0 AND 3.0-5.0 micrometers) - Reentry Phase

Radiometric		NEED	ARGUS IR Spectrometer	ARGUS IR Imaging System
Spectral Bands (micrometers)		0.7-1.1 1.4-2.5 2.9-3.8 NB2-5 0.7-5.0	0.7-5.5 Δλ = 3%	1.1-5.5 2.00-2.09 2.678-2.932 4.447-4.522 SF2
Range (kilometers)	Max	1000* (LM) 300** (RE)	----------	----------
	Min	200** (LM) 15** (RE)	----------	----------
Illumination (Day/Night)	Target	D** (LM) D/N** (RE)	----------D**	----------(LM) ----------D/N**----------(RE)
	Sky	N** (LM) D/N** (RE)	----------N**	----------(LM) ----------D/N**----------(RE)
Size (meter^2)		N/A	----------	----------
Emissivity		~0 to 1	----------	----------
App Temp (K)		N/A	----------	----------
Resolution (meters)		300-2100 (LM) 2 (RE)	N/A N/A	20-1000 (LM) 1.5-30 (RE)
SNR (dB)		10/20	≤0 to ≥40 Spectrally Dependent	NETD = 0.08°C SF2
Dynamic Range		10^6*	60 dB	------- TBR

*ERIM Interpretation **ERIM Supplied LM=Late Midcourse RE=Reentry

(OAMP) sensor recently developed by USASDC has LLWIR capability, and is to be made available to USAKA on a limited basis. An evaluation of this sensor's capabilities, as well as those of other new sensors, with respect to USAKA user needs is in progress and will be documented in the New Systems Analysis Report.

Some comments are in order related to how the shortfall designations appearing in Tables 4-9 through 4-13 were defined. Compared to the radars, both the user needs and existing capabilities in the optical regions are not well-defined. This is a natural consequence of the relative states of the optical and radar sensors at USAKA. The users, who are generally unused to receiving other than ground based visible optical data, are not prepared to state their needs for optical data as precisely as in the case of radar. Similarly, the well-established capabilities of the USAKA range radars are documented more completely (in terms of their characteristics relevant to satisfying USAKA user needs) than those of sensors that provide only occasional mission support.

As a result of the above situation, the definition of shortfalls in the optical regions was not as clear-cut as for the radars. For example, a straightforward application of the shortfall definitions would have resulted in an abundance of boxes labelled "TBR" -- to the point of overwhelming and obscuring the actual identified shortfalls. In order to avoid this situation, two steps were taken. Both of these involved ERIM's judgement regarding what are the salient technical issues associated with satisfying the user's optical data needs. The first step was to augment the collection of quantitative user need specifications. Such entries are noted in Tables 4-9 through 4-13 by either an asterisk or a double asterisk, signifying, respectively, an ERIM-interpreted value (i.e., a quantitative value derived from a qualitative user need statement) or an ERIM-supplied value. The second step was to assign to the TBR shortfall category only those items which were deemed highly significant but for which there was a lack of information.

In contrast to the above, no interpretation was applied to quantitative user need specifications. Indeed, these values were interpreted quite strictly, even when it was apparent that nominal values were supplied. For example, the visible band spectral requirement was specified as 0.4-0.7 micrometers, while the HALO visible sensors covers the region 0.42-0.65 micrometers; since the user need is not strictly met, this was classified as SF-3 (minor shortfall).

The single major shortfall (SF-1) identified in Tables 4-9 through 4-13 reflects the lack of coverage in specifically requested SWIR spectral bands (i.e., below 2 μm) by IRIS (Table 4-12). Several of the TBR items, however, such as sensitivity and dynamic range, may prove to be significant (SF-1 or SF-2). The intermediate shortfalls (SF-2) identified in Tables 4-9 through 4-13 nearly all relate to limitations in tracking slew rate or frame rate.

Shortfalls related to the two aircraft platforms associated with HALO/IRIS (which are both mounted in a single Learjet) and ARGUS are summarized in Table 4-14. As shown, the principal shortfall identified for each aircraft concerns the capabilities for time on station. However, the most serious shortfall associated with these platforms is not covered in Table 4-14, even though it relates to platform altitude. The user requirement of platform altitudes greater than or equal to 40,000 feet is still well below the sub-visible cirrus layers common to USAKA. These cloud layers occur routinely at altitudes up to 55,000 feet, and have proven to be serious obstacles to the optical data collection, particularly in the IR regions. They represent a significant challenge to establishing a reliable USAKA optical capability since no existing sensor aircraft, including OAMP and AST, can fly high enough to consistently be stationed above them.

In summary, the status of existing USAKA optical sensors with respect to user needs represents the major capability shortfall of the range. The shortfalls identified in Tables 4-9 through 4-14 represent an initial assessment of the potential for existing non-USAKA optical sensors to satisfy user needs. Although additional information is

Table 4-14
SHORTFALL SUMMARY
HALO/IRIS and ARGUS AIRCRAFT

Platform Characteristics	Need	HALO/IRIS	ARGUS
Altitude (K feet)	≥40	45	42-45
Time-on-Station (hours)	6	3-4 SF2	3-4
Positional Accuracy (meters RMS)	N/A	.05° roll, pitch 0.5° heading	463/hr CEP
			TBR
COM	N/A	------	------
			TBR

necessary to complete the assessment, clear gaps in spectral coverage (e.g., 5-9 μm, 13-24 μm, etc) are evident. An assessment of newly developed assets (OAMP, AST, etc) that may fill these gaps is ongoing and will be reported as part of the New Systems Analysis Report. Other issues such as spectral data capabilities have been provided by the specific programs and it is assumed they will continue to be provided by the projects as needed.

4.4 METEOROLOGICAL SYSTEMS

Despite the very considerable capabilities and expertise outlined in Section 3.6, meteorology forecasting and state determination remains an intractable problem due to the lack of a dense network of meteorological stations, the loss of GOES-West, the lack of appropriate mesoscale models, and user desire for information at a level of detail well beyond that normally required of meteorological measurements. It is, of course, not reasonable to suppose that these rather fundamental difficulties can be rectified by USAKA efforts, although both GOES-West and GMS are expected to eventually be replaced by the more capable GOES-NEXT series satellites. Despite the fact that most shortfalls in USAKA meteorological capability are due to factors well outside USAKA control (Table 4-15), there are three shortfalls sufficiently critical or tractable to warrant attention.

1) Measurement of high altitude cirrus. Cirrus frequently occurs above the ceilings of the HARP, AOA, HALO, Argus, and OAMP aircraft at Kwajalein. This cirrus is important both because it can play a role in re-entry physics and because it interferes with optical (especially M/LWIR) observations. It is usually visually apparent only at zenith angles >45°, so assessment is difficult. The addition of an uplooking lidar on the HARP would be able to detect and assess these clouds.

2) Acquisition or development of an all digital meteorological display/monitoring and modeling system. Currently, data

Table 4-15. **Shortfall Summary Environmental Data**

Measurement Accuracies

- Measurement accuracy is usually not a problem
  - Exception : Identification of subvisible cirrus
- Ability to perform measurement at desired location is significant problem
  - Large Geographical area, very limited land mass
  - Marginal satellite coverage
  - Aircraft expense, logistics, safety

Forecast Requirements

- Data base extremely sparse for prediction
  - Marginal satellite coverage
  - Sparse surface data
- Current models include only advection, not evolution

inputs received are a mixture of analog, digital and imagery. There is no common medium or format, and no quantitative, fast means to intercompare or intercalibrate all sources of data.

3) Development of USAKA - appropriate mesoscale meteorological models. Mesoscale meteorological models allow the user to predict meteorological events on a scale of hours on distances up to a few hundred kilometers with resolution down to the order of ten kilometers, i.e., the time and distance scales of interest in USAKA operations. While such models have been developed for US temperate latitude operation they would require adaptation to tropical conditions for USAKA use. This would be a considerable advance over the current capability, which consists solely of advecting (translating) observed weather features in response to observed winds.

5.0 GENERAL COMMENTS AND CONCLUSIONS

5.1 RADAR

Current radar capabilities satisfy user needs except in a few selected areas. A tally of major (SF-1), intermediate (SF-2) and minor (SF-3) shortfalls is provided in Table 5-1 along with the number of items which need to be resolved (TBR) for each radar frequency band.

The above shortfalls have been identified from explicitly stated user needs. Two other major shortfalls have been identified from a consideration of operating methods. These are:

(1) Lack of multiple target tracking and simultaneous fine resolution imaging of all tracked targets.

(2) Lack of capability to acquire, sort, identify and reliably hand over large target trains.

The latter need will become increasingly important in the future for operational cost efficiency as more and more tests are configured on a single launch vehicle.

As yet, user expressed needs only weakly support a need for an X-band signature radar. Several multiple target tracking and imaging needs have been expressed for the X-band frequency domain but are, for the most part, not dependent upon wavelength.

For the most part, user needs do not reflect the future need for increased radar sensitivity to accommodate potential RCS reduction which may be possible with stealth materials or coatings. Greater sensitivity will be required to simply maintain current operating

TABLE 5-1

SUMMARY CHART

RADAR SHORTFALLS

Frequency Band	Major Shortfalls (SF-1)	Intermediate Shortfalls (SF-2)	Minor Shortfalls (SF-3)	To Be Resolved (TBR)
VHF	0	3	4	4
UHF	0	3	3	4
L	0	1	1	3
S	0	3	1	6
C	0	3	4	4
X	1	0	0	1
K_a	0	3	2	8
TOTALS	1	16	15	30

ranges. Consequently, a continuing program of improvements in sensitivity for selected radars is recommended. A variety of ongoing radar upgrades are directed toward this goal.

5.2 TELEMETRY

Currently, most of the existing user needs are satisfied by the telemetry capabilities at USAKA. However, future user needs have indicated a shortfall in data reception in the area of data bit rates and recording bandwidth. In addition, there may be the need for an increase in the number of tracking antennas with improved dynamics to accommodate the tracking of multiple instrumented reentry vehicles and USAKA launched interceptors. A tally of telemetry shortfalls is provided in Table 5-2.

5.3 OPTICS

Figure 5.1 summarizes the shortfall assessment of the existing USAKA optical sensors. The lack of capability in any spectral region except the visible, as well as the disadvantages associated with sea-level platform locations removes these sensors from serious consideration with respect to satisfying user needs. Consequently, the shortfall analysis in this report concentrated on available airborne sensor systems.

Table 5-3 summarizes the shortfalls identified in Section 4.3 for the HALO, IRIS and ARGUS sensor systems. The major shortfall tally includes the lack of any LWIR or LLWIR capability and the problem of cirrus layer vs. aircraft platform altitudes.

Table 5-2
SUMMARY CHART
TELEMETRY

	Major Shortfalls (SF-1)	Intermediate Shortfalls (SF-2)	Minor Shortfalls (SF-3)	To Be Resolved (TBR)
Telemetry Reception	0	3	0	0
Antenna System	0	0	0	2

Figure 5-1. **SHORTFALL SUMMARY**

USAKA Ground-based Optical Sensors

Only existing capability continuously at USAKA is ground-based sensors that provide endoatmospheric metric, signature and photodocumentation. Optical signature data is limited to visible region, and is of low radiometric accuracy. Exoatmospheric metric data may be obtained under specific illumination conditions.

- Major Shortfalls
  - Lack of signature capability in UV, SWIR, MWIR, LWIR, LLWIR
  - Lack of integrated airborne platform which would reduce atmospheric losses
  - Lack of reliable exoatmospheric (i.e., late midcourse phase) signature and metric capability

TABLE 5-3
SUMMARY CHART
OPTICAL SHORTFALLS

Spectral Region	Major Shortfalls (SF-1)	Intermediate Shortfalls (SF-2)	Minor Shortfalls (SF-3)	To Be Resolved (TBR)
Ultraviolet				
HALO	0	2	0	1
Visible				
HALO	0	1	0	0
ARGUS	1	1	2	1
SWIR/MWIR				
IRIS	1	1	1	1
ARGUS	1	3	0	2
LWIR	1	N/A	N/A	N/A
LLWIR	1	N/A	N/A	N/A
Platform				
HALO/IRIS	1*	1	0	2
ARGUS	1*	1	0	2
TOTALS	7	10	3	9

*ERIM supplied

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