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A Discussion of the Requirements and Methods for Validating Range Surveillance and Clearance Aircraft

Shawn Michael Disarufino
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Shawn Michael Disarufino entitled "A Discussion of the Requirements and Methods for Validating Range Surveillance and Clearance Aircraft." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

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We have read this thesis and recommend its acceptance:

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Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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A DISCUSSION OF THE REQUIREMENTS AND METHODS FOR VALIDATING RANGE SURVEILLANCE AND CLEARANCE AIRCRAFT

A Thesis Presented for the Master of Science Degree
University of Tennessee, Knoxville

Shawn Michael Disarufino
August 2006

DEDICATION

I would like to dedicate this thesis to my wife who assumes far too much responsibility and receives far too little praise. Allison, I love you.

"An excellent wife who can find?
She is far more precious than jewels. The heart of her husband trusts in her,
and he will have no lack of gain. She does him good, and not harm,
all the days of her life" Proverbs 31:10-12

ACKNOWLEDGEMENTS

I would like to thank the following people who were instrumental in the completion of this thesis: My family for putting up with countless hours of my absence. Mr. Mark Bowling, flight test technician extraordinaire, who patiently taught me everything I know today about flight test and kept me sane when dealing with “the man”. Bob Jacob, an invaluable resource regarding range operations and safety. Wayne Patterson, who always made himself available and showed incredible patience in explaining his program. Lastly, Mr. Richard Ranaudo who’s meticulous guidance and thoughtful insight were critical to this thesis successful completion.

ABSTRACT

Conducting weapons test in the U.S. Navy's Point Mugu Sea Test Range requires clearing a hazard pattern using aircraft equipped with surface search radar to ensure that inert debris from a weapons system test does not impact non participating vessels or personnel. This mission is referred to as range surveillance and clearance.

The purpose of this thesis is to discuss a standardized method that objectively validates an aircraft for use as a range surveillance and clearance asset. The goal is for the method to be cost effective, easily repeatable, adaptable to as many different types of airborne assets as possible, and one which provides the range authorities a high confidence and defendable method to accept an aircraft as suitable for the mission.

The proposed method was created from a study of range clearance procedures and requirements. The study included review of directly applicable and analogous test instructions and interviews with range safety personnel, subject matter experts on radar, and experienced mission operators (aircrew and surface surveillance). The method was also based on the author's experience as project officer responsible for testing an aircraft for this mission.

The investigation led to the creation of a list of objective requirements, primarily found in current instructions. An organizational process was then defined with the purpose of providing a structure by which roles and responsibilities are assigned, as well as to delineate the final approval authority for the process. Next, a method was developed that uses information gathered about the aircraft under consideration and compares it against the requirements through a preliminary review. This review consists of a computer simulation of expected radar performance and a comparison of basic aircraft performance and capabilities such as range, endurance and speed. Once the preliminary review is complete, the aircraft is evaluated during a ground systems preflight check and a flight test. These evaluations are designed to provide qualitative and quantitative data that can be analyzed to determine if the aircraft under consideration meets the established requirements. Lastly, a method for determining the degree to which the test aircraft met the requirements is presented. This method is explained using available historical data

from a flight test report which evaluated a C-130 aircraft configured with AN/APS-115 surface search radar for the range surveillance and clearance mission.

The findings of this study indicate that it is possible to develop a generic method for validation that would give the Range Commander a high confidence that aircraft utilized in this mission are suitable for the tasks required. Although many of the test instructions consulted and the author's experience were primarily related to the Point Mugu Sea Test Range, the results of this thesis could be applied to any test range requiring the use of a range surveillance and clearance aircraft.

PREFACE

The intention of this thesis is to explore the possibility for providing a standardized method for future requirements. Although Department of Defense publications and instructions were used as a basis for analysis, the conclusions presented are solely the opinion of the author and in no way reflect Navy or national range policy. All material presented is Unclassified.

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LIST OF ABBREVIATIONS

ACC	Assessment Color Code
ACDS	Advanced Combat Direction System
ADIZ	Air Defense Identification Zone
AGL	Above Ground Level
AIC	Air Intercept Control
AN/APS-115	Designation for Airborne Search Radar
AREPS	Advanced Refractive Effects Prediction System
BIT	Built in Test
CRD	Capabilities Requirements Document
CRM	Capabilities Requirements Matrix
dB	Decibels
dBsm	Decibels-Square Meter
DOD	Department of Defense
ELT	Executive Leadership Team
FM	Frequency Modulation
GHz	Gigahertz
GPS	Global Positioning System
HSMST	High Speed Maneuverable Seaborne Target
IMC	Instrument Meteorological Conditions
INS	Inertial navigation System
KIAS	Knots Indicated Airspeed
Knots	Nautical Miles/Hour
kW	Kilowatt
MSL	Mean Sea Level
NATOPS	Naval Aviation Training and Operating Procedures Standardization
NAVAIR	Naval Air Systems Command
Nm	Nautical Miles
POD	Probability of Detection
RC	Range Commander
RCS	Radar Cross Section
RDT&E	Research, Development, Test and Evaluation
RSC	Range Surveillance and Control
SAR	Search and Rescue
TACAID	Tactical Information Document
TACAN	Tactical Air Navigational Aid
UHF	Ultra High Frequency
Vc	Design Cruise Airspeed
VHF	Very high Frequency
VID	Visual Identification
VMC	Visual Meteorological Conditions

Vne	Not to Exceed Airspeed
VOR	VHF Omnirange Station

CHAPTER I. INTRODUCTION

Background

Testing weapons is an inherently hazardous activity that requires careful planning and meticulous coordination to ensure a safe operation. Of particular concern to the Navy is avoiding a mishap with non-participating civilian personal or equipment. Besides the initial damage, a mishap of this kind could have far reaching public relation implications and possibly cause the cancellation of a weapons program. One only need examine the recent mishap where a U.S. submarine collided with a civilian Japanese vessel to realize the impact an incident of this kind can have on human life and to a lesser extent, the image of the Navy.[1]

One method the Navy uses to avoid this type of mishap is to use a radar equipped aircraft to conduct surface search to ensure that non participants are clear prior to declaring a "green range" (range is ready for test). Working in coordination with a range surveillance control facility, the aircraft conducts sweeps and determines course and speed of contacts. If a contact will potentially enter, or "foul", the range during test, the surveillance aircraft may be directed to fly over the vessel and contact it via radio to attempt to resolve the conflict. This mission is referred to as range surveillance and clearance.

Mission Description

The Point Mugu Sea Test Range, as presented in Figure 1, is a large complex projecting out from the Naval Air Station Point Mugu and covering 36,000 $miles^2$. Although the vast size of the area provides the Range Commander (RC) with opportunity for isolating non participants from inert debris; it also presents a formidable problem in terms of monitoring test areas.

[1] Thomas E. Ricks and Paul Arnett," U.S. Sub and Japanese Boat Collide," Washington Post, 10 February 2001, sec. A, p.1.

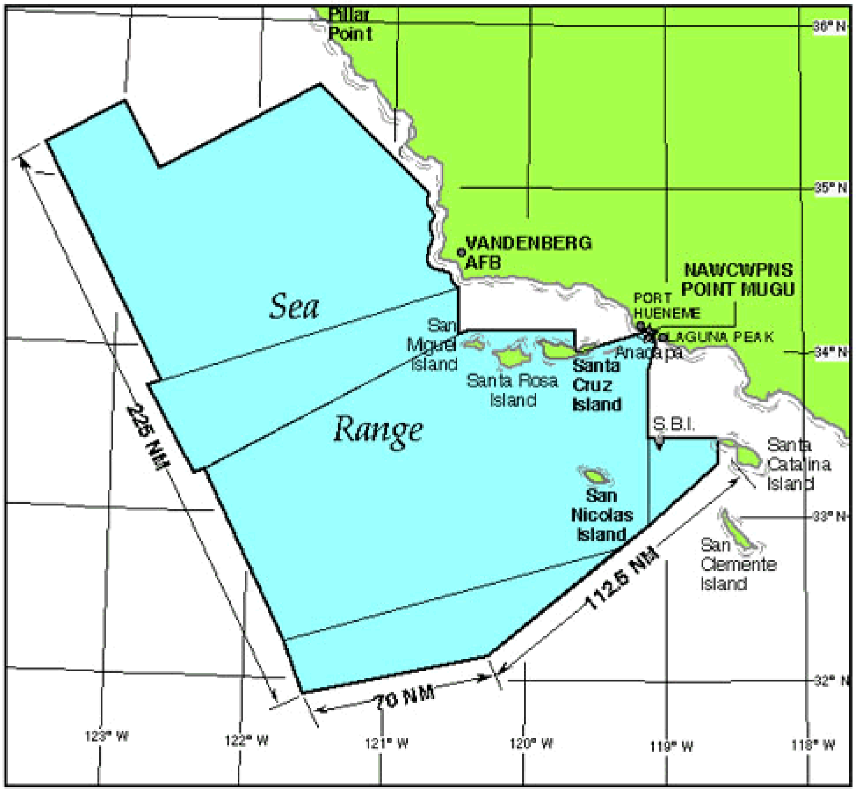

Figure 1. Point Mugu Sea Test Range[2]

The task is made easier when a smaller test area is defined by the type of test involved.

When a test mission is proposed that would present an inert debris hazard, the Range Commander is responsible to ensure the safety of the test within acceptable limits. The Range Commander's Council Standard 321-02, and its supplement provide a "common set of debris protection policies, risk criteria, and guidelines to protect personnel and assets during manned and unmanned flight operations."[3] The common policies proposed by this directive step through an analysis that define what type of debris could be generated from various weapons tests, where it would propagate, how lethal the debris would be on impact, and the probability of risk to personnel and assets.

[2] Naval Air Warfare Center Weapons Division Code 5200D, "Functional Requirements for Sea Range Air and Sea Surveillance and Air Intercept Control," Data Repository Group Office DRGO-6255-9982, 21 June 2004, 1.

[3] Range Commanders Council, "Common Risk Criteria for National Test Ranges," Standard 321-02, June 2002, 1-1.

The overall safety standard is written such that the risk exposure probability to an individual is not more than 1×10^{-6} on an annual basis.[4]

To more thoroughly understand the range safety process, one must consider a notional scenario of an airborne weapon system test launch. The range safety office would analyze the test scenario to determine a debris hazard pattern as shown in Figure 2. The small solid box represents the area that could potentially be affected by debris at the weapon launch point. Because the pattern could be oriented in any direction depending on the circumstances at the time of launch, the hazard pattern is typically defined by a circle. The size of the circle is calculated by the maximum distance that the weapon can travel and the probabilistic distribution of debris with margins included to account for

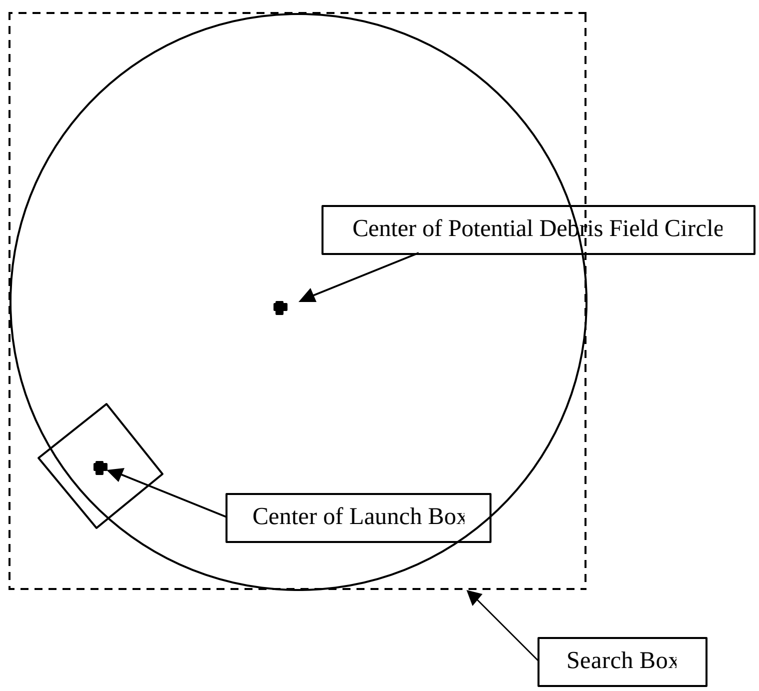

Figure 2. Example of Debris Propagation and Associated Hazard Pattern[5]

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[4] Ibid, 3-1.

[5] Naval Air Warfare Center Aircraft Division, "Range Safety Approval for ASRAAM Weapon Separation Test at Atlantic Offshore Warning Area W-386," 26 April 2001, Appendix B.

error. As the weapon travels away from the launch box, the area that could potentially be affected by debris expands because directional errors induced by system problems or external variables such as winds are exacerbated over distance. For example, a 5 degree launch heading error would cause a weapon to be off course only approximately 1/12th of a mile after traveling 1 mile. But that same error would result in more than a 2 and 1/2 mile error if the weapon traveled 30 miles. Once the hazard pattern is determined, a search pattern defined by a square whose sides are equal to the diameter of the hazard pattern is assigned to provide a simple search box for clearing.

With the above understanding of the bounded scope of the mission the Range Commander attempts to avoid a mishap by ensuring that calculations are done correctly to keep debris within the search area and that the area is properly monitored to ensure that non participants are outside of the search area. The airborne range surveillance asset is often relied upon in accomplishing the latter task and therefore range authorities should have a high confidence in its capability to perform the mission. The criteria for an aircraft to perform the range surveillance mission are based on its ability to fully support these range safety requirements.

Problem Statement

The Navy's Point Mugu Sea Test Range has historically utilized P-3 variant aircraft to perform the range surveillance and clearance mission. However, due to airframe attrition the Range has been forced to consider alternatives, both military owned and civilian commercial contract aircraft. As one alternative, the Naval Air System Command (NAVAIR) executive leadership team (ELT) directed modification of two C-130 aircraft with AN/APS-115 surface search radars as a recapitalization effort for future range support. [6]

As project officer for this effort, the author discovered that the Point Mugu Sea Test Range lacked clear instructions, methods, procedures and processes to confidently accept a newly proposed aircraft for use in the range surveillance and clearance mission.

[6] Naval Air Warfare Center Weapons Division, "KC-130 Range Surveillance and Clearance Mission APS-115 Flight Test Program," Test Plan Number P2005-08-569AO, 19 Aug 2005, 1.

The Functional Requirements for Sea Range Air and Sea Surface Surveillance and Air Intercept Control document passively states that verification should be done, and synoptically describes the methods that may be used to validate an asset.[7] However, it is inadequate to determine what must be accomplished.

A barrier to creating a single standard has been reluctance by range safety and operations authorities to sanction aircraft without fully investigating all of the potential variables. This is not practical to achieve because of the excessive number of data points required to characterize every potential variable such as target type, environmental conditions, and angle of reflection. This reluctance has resulted in the more undesirable situation of no existent standard.

Proposed Solution

It is possible to provide a qualitative and quantitative decision making tool to the Range Commander. The standard by which the Range Commander's Council (RCC) judges the risk of inert debris can logically be applied to any safety mechanism on the range such as range surveillance aircraft. "The intent of the safety criteria is to provide definitive, measurable, numerical criteria to protect people….Definitive criteria provide a standard by which the RC's [Range Commander's] actions can be compared to those of any reasonable person in similar circumstances."[8] Following this less stringent yet definable goal, a method can be developed which validates an aircraft within an achievable test schedule and budget while still producing a high confidence result. Furthermore, the method, once developed, can be improved over time if deficiencies in testing become apparent.

This thesis will develop a list of requirements that an aircraft must be able to comply with to adequately perform the range surveillance and clearance mission. These requirements will be developed from an investigation of existing range instructions as well as from the author's mission experience. An organizational process will be proposed that defines the roles and responsibilities of personnel associated with, and approval

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[7] "Functional Requirements for Sea Range Air and Sea Surveillance and Air Intercept Control," 2.
[8] Range Commanders Council, "Common Risk Criteria for National Test Ranges", Supplement to Standard 321-02, June 2002, 1-1.

authorities for, validating a proposed aircraft. Next, a method will be developed that will be designed to be useful with any generic aircraft. Utilizing the method will produce data which may be analyzed and compared against the requirements. This analysis can then be condensed into a report which can be reviewed, approved, and archived for later use. Lastly an explanation of the process for assessing the degree to which the aircraft met the requirements will be presented.

CHAPTER II. REQUIREMENTS

To create a viable test method, the capabilities of an aircraft and radar system must be understood. This chapter will review the current instructions used to determine mission requirements. Additionally, the rationale for a newly established requirement is explained. Lastly, the product of the requirements is presented in the form of a capabilities requirement matrix (CRM) from which the test method is determined.

Currently Defined Requirements

Two sources were used as a basis for defining the new proposed requirements. The first source was the Capabilities Requirement Document (CRD) for the NC-130F Range Support Aircraft 138319[9]. The CRD is a document that describes the objectives and minimum requirements for the C-130 aircraft to be considered acceptable for its various missions including range surveillance and clearance. The document was signed by NAVAIR Range Department, Associate Department Head for Pacific Range and therefore it will be assumed that the requirements specified for that mission were at the least minimally acceptable to the Point Mugu Sea Test Range authorities.

The second document is the Functional Requirements for Sea Range Air and Sea Surface Surveillance and Air Intercept Control which "establishes functional requirements for air surveillance, sea surface surveillance, and Air Intercept Control (AIC) at the Sea Range."[10] The document contains airborne surveillance quantitative radar performance characteristics which are considered to be minimum acceptable requirements. The parameters drawn from this instruction for incorporation as test criteria for this thesis were the most stringent requirements for the Sea Range outside of the Air Defense Identification Zone (ADIZ), which excludes radar cross sections (RCS) less than 3 m^2. Smaller targets such as kayaks are discounted due to fact that they are considered unlikely to venture outside five nautical miles (nm) from shore where research development test and evaluation (RDT&E) events normally occur.

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[9] Naval Air Warfare Center Weapons Division, "Capability Requirements Document for the NC-130F Range Support Aircraft (RSA) 138319," 13 January 2005, A-2.
[10] "Functional Requirements for Sea Range Air and Sea Surveillance and Air Intercept Control," 4-5.

Proposed New Requirement

A new requirement is proposed adding to those drawn from the existing instructions in order to ensure that the aircraft tested will be fully capable of performing the range surveillance and clearance mission. This requirement is a minimum cruise airspeed (Vc) selected to meet the minimum time to clear 20,000 miles^2 (3 hours), and to be capable of visual identification (VID). Without a minimum airspeed a dirigible could conceivably meet all of the technical and endurance parameters as well as visually identify targets, however, it could never prosecute a contact in a timely manner in order to continue with test. A Vc of 150 knots indicated airspeed (KIAS) is a value which was determined using the following rationale: 20,000 miles^2 could be represented by a box of approximately 142 nm sides as represented in Figure 3.

Assuming this notional clearance area, an aircraft located in the center would have 100 nm to travel to any corner of the square. A Vc of 150 KIAS, no wind, would allow the aircraft to VID a target at the corners within 45 minutes of tasking. Adding this

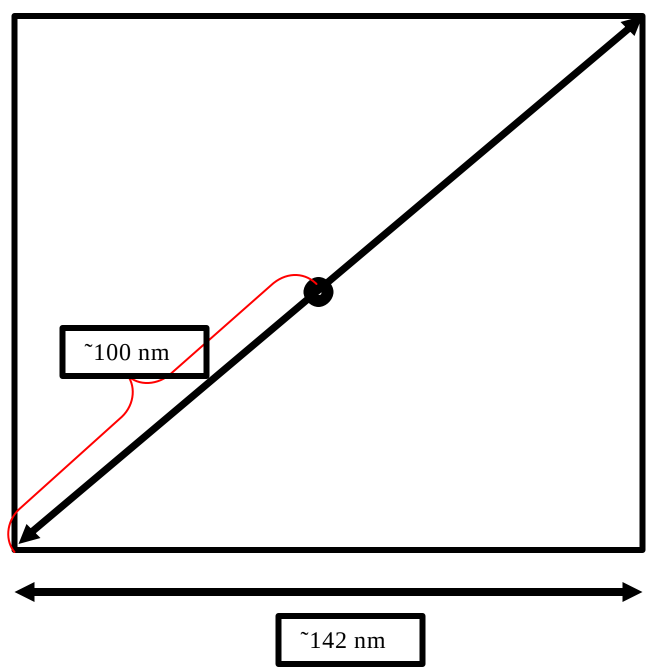

Figure 3. Notional Clearance Area Representing 20,000 miles^2

time to the time to perform two full sweeps of the notional clearance area exceeds the 3 hour clearance requirement by approximately 30 minutes but is considered acceptable as a minimum requirement.

Capabilities Requirements Matrix

A Capabilities Requirements Matrix (CRM) was developed by collating the proposed new minimum cruise speed requirement with the currently defined requirements. The CRM is needed to organize the critical requirements of the range surveillance and clearance mission into one source. The items were incorporated based on the author's experience with the mission and included all of the range surveillance and clearance requirements of the CRD. Selected requirements were drawn from the Functional Requirements for Sea Range Air and Sea Surface Surveillance and Air Intercept Control[11] in order to fully define the aircraft and radar capabilities for the proposed method. Items from this document that were excluded from the CRM were either redundant or not critical for validation purposes.

The CRM is the acceptance criteria that will have to be satisfied by any flight asset that may be evaluated for this mission. Two types of capabilities are represented in the matrix. The first being aircraft capabilities. Because the radar resides as part of a system in an airframe it is essentially useless unless the aircraft can meet minimum requirements such as endurance, navigation, communications, etc. The second type focuses on the technical aspects of the radar itself. These criteria will define aspects such as maximum range, track capability etc. The CRM is presented in Table 1 and is color coded to indicate the source from which the requirement is drawn.

[11] Ibid.

Legend
CRD 138319
DRGO-6255-9982
New Requirement

Table 1. Capabilities Requirements Matrix

	Parameter	Requirement
Aircraft Requirements		
1	Endurance	Provide clearing activities with single or multiple units for seven hours at 150 NM from test and evaluation base.
2	Cruise Airspeed (Vc)	Capable of maintaining at least 150 KIAS
3	Search Speed	Surveillance of 20,000 miles^2 area, at 150 nm from nearest airfield, within three hours
4	Navigation	Identify hazard area boundaries with ±0.5 nm accuracy
5	Communications	Range control has connectivity with surveillance asset throughout test and evaluation event
6	Communications	Provide VHF/FM radio communication capability with surface contact
7	General	Provide visual identification (VID) of surface contacts by reading vessel name
Radar Requirements		
8	Radar Detection	3 m^2 RCS represented by 20 ft sailboat or 18 ft Boston whaler
9	Radar Detection	Radar surface detection of 3 m^2 RCS target with 90% 1st pass probability of detection (POD)
10	Target Accuracy	Identify surface contact within ±0.5 nm accuracy
11	Radar Processing	Determine target course (true, relative) to ±5 degrees
12	Radar Processing	Determine target speed to ±3 knots
13	Radar Processing	Label and maintain multiple contacts
14	Weather/Surface Conditions	Effective in VMC/IMC with surface winds to 25 knots, Sea State 4

CHAPTER III. PROPOSED VALIDATION METHOD

The method proposed is intended to produce a high confidence result in one logical, standardized, and cost effective (in terms of schedule, manpower, as well as actual funds expended) method. In applying this method, a candidate aircraft will be analyzed using computer modeling and mathematical comparison, ground and flight testing, all with the goal of evaluating performance versus the specific capabilities requirements from the CRM. The method will determine if the candidate aircraft meets the acceptance criteria for use as a range surveillance and clearance mission asset. The results of the validation test will be compiled in a report and are reviewed and approved by range authorities. The report is then archived so that it may be updated or referenced as required. A process for administering the proposed validation method is described that takes into account the existing organizational and command structure relating to range surveillance and clearance.

Process to Validate Proposed Aircraft

The process to approve an aircraft for the range surveillance and clearance mission must culminate in an approval at the proper level of authority. With that goal, this thesis proposes that an instruction should be created which delineates the requirements for, and the process to approve, a range surveillance aircraft. The Naval Air System Commands Range Department (NAVAIR 5.2) is the organization within NAVAIR which is responsible for managing the "the resources required to operate and sustain all NAVAIR ranges by providing safe, instrumented, controlled testing…"[12] and therefore is the logical approval authority for the proposed instruction. Figure 4 presents the organizational structure of NAVAIR 5.2 as it relates to the execution of the proposed instruction.

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[12] Naval Air Systems Command Instruction 5400.1C,"Naval Aviation Systems Team Organizational Manual," 7 August 2000 (Draft Revision).

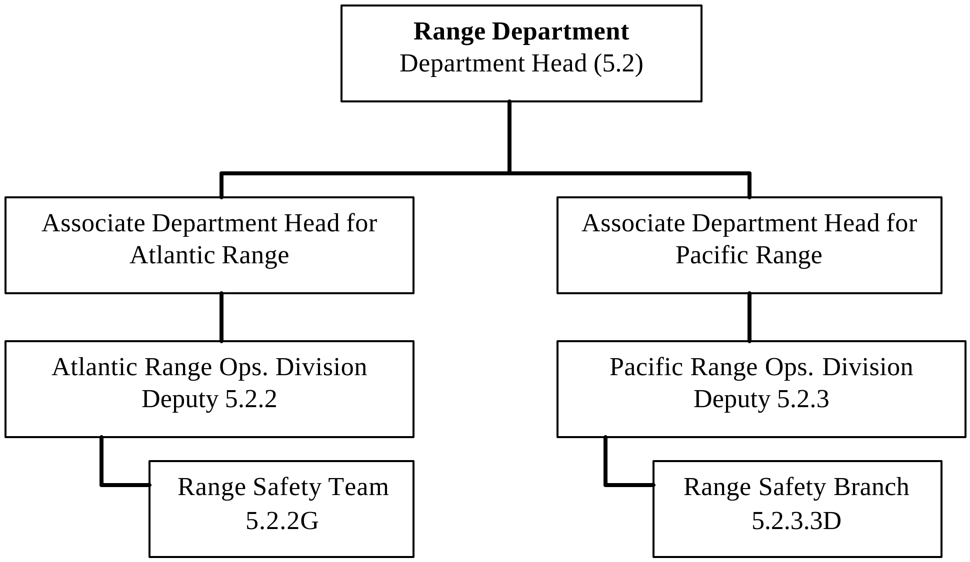

Figure 4. NAVAIR 5.2 Organizational Structure[13]

The instruction should delegate the specific approval authority for range surveillance and clearance assets to the Atlantic and Pacific Range Associate Department Heads. The Associate Department Heads provide the leadership and policy guidance for their specific area of responsibility.

The Range Operation Division Heads are charged with safely conducting all operations on their respective ranges and as such shall be responsible for executing the validation testing of candidate range surveillance and clearance aircraft. When an aircraft is proposed for the mission, the Range Operations Division head will assign a project test engineer from the division to administer the validation method. The project test engineer will be responsible for the following items which will each be explained in subsequent paragraphs. First, the project test engineer will collect specific aircraft and radar data from the custodian of the proposed aircraft via an input data sheet. The project test engineer is also responsible to ensure the data comes from reliable reference material (e.g. Naval Aviation Training and Operating Procedures Standardization (NATOPS)). Next, using the input data, the project test engineer will conduct a preliminary CRM

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[13] Ibid.

comparison to determine suitability of the candidate aircraft and radar versus the critical requirements. The project test engineer will then schedule a flight test event including coordinating the availability of the test facilities, target boat, and range area required for completion. Lastly, the project test engineer will collate and analyze the data and provide a recommendation through a report of validation test results. The report will be routed through the Range Safety office and Range Operations Division Head, each of which can add recommendations if required. Finally, the Associate Range Department Head will review and either approve or reject the aircraft as a suitable asset.

Preliminary CRM Comparison

The expected suitability of the proposed system, both for the radar and the aircraft, can be evaluated prior to flight test by using computer simulations and mathematical comparisons based upon available manufacturers specifications. This is a favorable approach in that it is cost effective, standardized, and can serve to exclude specific aircraft, radars, or systems without having to invest the manpower or budget for actual test. Also, since it would be impossible to flight test every variable such as target size, sea state, etc., this preliminary comparison provides an expeditious means of assessing a candidate aircraft against a broad range of conditions that help to define flight test requirements. The flight test can then be designed to selectively validate points of interest. Lastly, performing a preliminary CRM comparison of the aircraft and radar provides an historical catalogue which can be used to refine future tests, and a means for comparing future proposed range surveillance assets. Following the form of the CRM, the comparison assesses the candidate aircraft and radar as an integrated system, and as separate components of the system.

Input Data Sheet

A data sheet will be used as the basis to conduct the preliminary CRM comparison of the aircraft and radar performance as compared to those in the CRM. The input data sheet was created from the author's experience and was designed to provide information essential to understanding the expected performance of the aircraft or radar. The data sheet will be completed by a representative of the organization which owns the aircraft that is being considered. The information presented is derived from aircraft publications and manufacturers' specifications. The proposed data sheet is divided into general information, aircraft specific data and radar specific data and is presented in Figure 5.

Aircraft (data sheet items 6-16)

The data provided in these items are a qualitative and quantitative look that assists the project test engineer in formally documenting the aircraft under consideration. Questions that occur as a result of the submission can be addressed by control and item number of the data sheet. For example if the VHF frequency range (item 13) submitted did not cover marine frequency, the proposing agency could be queried to determine if they can easily augment their aircraft to add this capability. If the answer is no, then the proposal is rejected and no further energy is expended on it.

Radar(data sheet items 17-28)

These data are required by the advanced refractive effects prediction system (AREPS). AREPS is a model developed by the Space and Naval Warfare Center which provides a powerful tool for predicting many types of electronic propagation, including radar. The program can accept multiple radar and target types and can be configured to display range and probability of detection[14]. The data required can be obtained through a database maintained by the Space and Naval Warfare Center or can be obtained from manufacturers' specifications and entered manually. Although there are many models which may be used to predict radar system performance, AREPS is the most logical to use in this application because it was developed by a Naval resource, it can be used free of charge, and is a simple application that runs on Windows® based desktop computers.

[14] Wayne L. Patterson, "Advanced Refractive Effects Prediction System," Space and Naval Warfare Systems Center.

Range Surveillance and Clearance Aircraft Data Sheet

1.Date of Request	2.FOR RANGE ADMIN USE ONLY **CONTROL NUMBER** →	
3.Proposing Agency	4.Point of Contact	5. Contact Phone/e-mail

AIRCRAFT DATA

6.Aircraft Type	7.Endurance (HR:MIN)	8.Max Range (NM)	9.Vne	10.Vc (or search speed if different)

11.Navigation Source (circle all that apply) VOR TACAN INS GPS Other:	12.UHF Frequency Range	13.VHF Frequency Range	14. Can aircraft accommodate a passenger/evaluator for test flight? **Y/N**

15 Cost Per Flight Hour	16. Briefly Describe Visual Identification Method:

RADAR DATA (1)

17.Radar type/model number	18.Frequency(MHz)	19. Peak Power(kW)	20. Pulse Length(μs)
21. Receiver noise figure(dB)	22.Assumed System Loss (dB)	23.Max instrumented range(nmi)	24.Pulse rate(Hz)
25. Antenna Gain(dBi)	26. Antenna scan rate	27. Horizontal Beam Width	28. Vertical Beam Width

Note (1): RADAR input data derived from AREPS inputs, other programs may require additional/different data

Figure 5. Proposed Aircraft Data Sheet

Analysis of Radar Data

With the inputs from data sheet items 17 through 28, AREPS can create a graph as presented in Figure 6. The example presented predicts the probability of an airborne early warning aircraft flying at 5,000 ft detecting a 10m^2 RCS surface target.

The colored dashed horizontal lines are a reference extension of the POD percentages described by the vertical axis. The thin black line describes the predicted probability of detection (POD) by the example radar as a function of range. The free space reference red line is an indication of the best performance that could be expected of the example radar if there were no propagation loss. From this depiction we would expect this radar to effectively detect the selected target from approximately 10 nm to a distance slightly greater than 45 nm.

The above graph will be reproduced for a small sized surface target (3 m^2 RCS) as defined by the functional requirements document[15] The maximum range predicted by the AREPS model will be used to determine maximum range flight test distances.

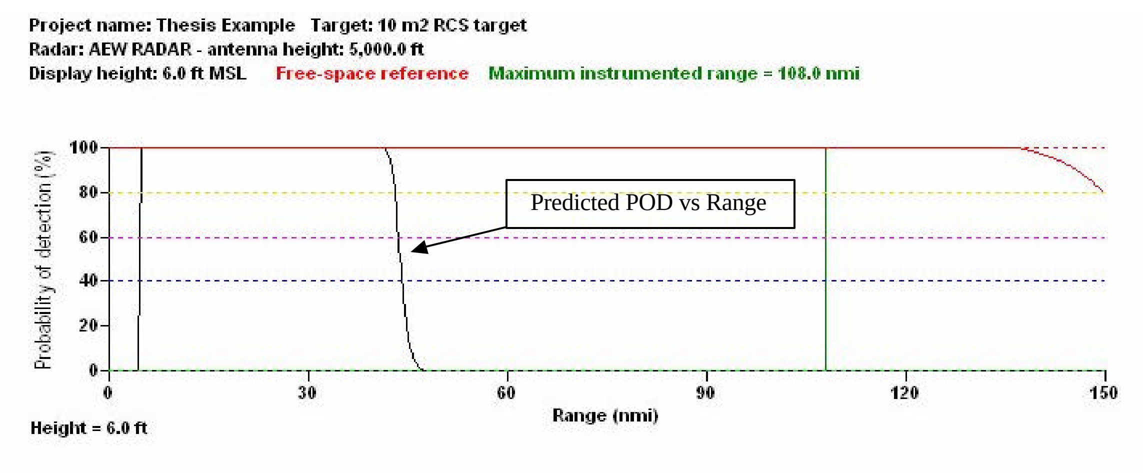

Figure 6. AREPS Probability of Detection (POD) versus Range[16]

[15] "Functional Requirements for Sea Range Air and Sea Surveillance and Air Intercept Control," 4-5.
[16] Source AREPS version 3.6.01.45 08 May 2006, used by permission

Preflight Systems Check

A comprehensive functional ground test of the radar is beyond the scope of the validation flight in that it would require an extensive budget to produce adequate data for comparison. There is a need, however, to expand the routine preflight of a candidate aircraft before a test flight. The purpose is to ensure that critical aircraft systems, which include communication, navigation, and radar systems are all operating within specification. Specific system deficiencies can be noted and if needed the flight test can be delayed or rescheduled until the degradations can be corrected Specifically the preflight systems check at a minimum should verify the following:

- Communications (UHF, VHF/FM)
- Radar system Built in Tests (BIT)
- Functionality of radar operating modes.

Additionally, if an evaluator will be accompanying the proposed aircraft during test, an expanded preflight check is an opportunity to familiarize the evaluator with the system functions that will be observed. A proposed preflight systems check card is presented in appendix A, Figure 15.

Flight Test

<u>*Available Test Facilities/Equipment*</u>

Range Surveillance and Control (RSC)

The Point Mugu Sea Test Range employs a division of personnel with expertise in coordinating and controlling the range through tracking air and surface targets with land based air search and surface search radars. These RSC capabilities can be used during a validation test event to log aircraft position versus contact position. Range and bearings called out by aircraft can be verified in post mission analysis to ensure accuracy. On each mission, an RSC individual is stationed as a "surface tracker". The surface tracker logs all contacts on a paper surface plot by time, position, and course and speed relative to the hazard pattern.[17] During any test event, the RSC surface trackers mark radar contacts prior to test and utilize the Advanced Combat Direction System (ACDS) to follow them as they move in relation to the range area which must remain clear. Surface craft that have the potential to foul the range can be identified prior to test events as contacts of interest.

High Speed Maneuverable Seaborne Target (HSMST)

A High Speed Maneuverable Seaborne Target (HSMST), as depicted in Figure 7, available through the NAVAIR seaborne targets engineering branch, Port Hueneme, California, is highly desirable for use during test. The HSMST is a rigid inflatable boat with an aluminum hull and has previously been considered by range authorities to be comparable with the smallest type of craft that would be encountered on the Point Mugu Sea Test Range.[18] The HSMST has GPS and navigational equipment onboard that can record its own position versus clock time for the entire test period which can be used to correlate target position data in post mission analysis.

Additionally, the HSMST has been characterized in an anechoic chamber and therefore provides a known target RCS for evaluating a potential radar system. Figure 8 is a depiction of the composite RCS signature for radar frequencies from 8 to 12 Gigahertz (GHz). The composite signature graph gives an approximation of the type of radar return the HSMST produces at various aspects, with 0 degrees representing directly bow on, and 180 degrees representing the stern. The signature is reported on the vertical axis in RCS decibels m^2 (dBsm). For comparison, a 3 m^2 RCS return is represented by approximately 4.78 dBsm.

As demonstrated in Figure 8, the HSMST's radar cross section varies greatly from less than 3 m^2 RCS in the bow region to greater than 100 m^2 RCS when painted directly

[17] Naval Air Systems Command Weapons Division, Point Mugu, "Policy for Sea Range Surveillance and Clearance", 20 February 2003 (DRAFT), 9.
[18] Leonard Hartsook, "Test Plan for the AIRTEC King Air A100 Airborne Surveillance Radar OP Number SR14646," 26 Apr 2004. 2.

Figure 7. High Speed Maneuverable Seaborne Target (HSMST)[19]

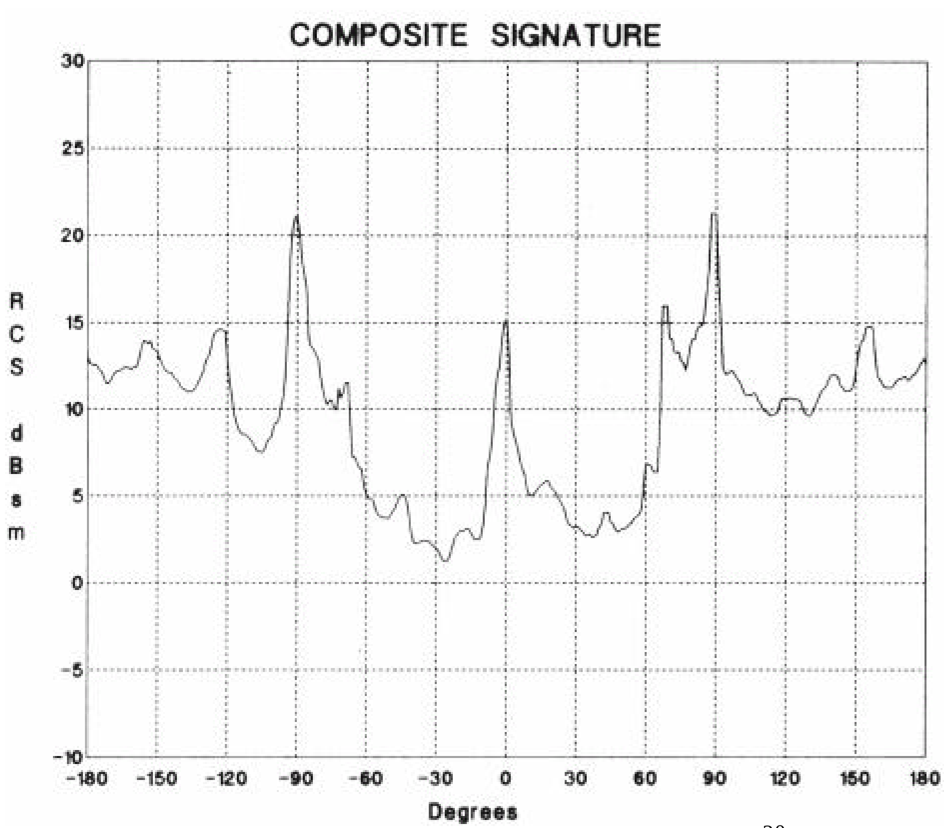

Figure 8. Composite RCS Signature 8-12 GHz[20]

[19] Leonard Hartsook, "Report on the AirTec King Air A100 and its AN/APS-143 Airborne Surveillance Radar Test," 27 Apr 2004.6.

abeam. Therefore, the flight test procedures should consider the aspect of the HSMST to ensure the target is presented in the lower RCS regions.

Proposed Test Mission Profile

A standard test profile was created to address all 15 items of the CRM either directly or through extrapolation. Although the goal is to validate each requirement with a high degree of certainty, the test should be limited to account for the following natural constraints. First, in keeping with the goals of this thesis, the proposed method is not intended to be a developmental test of a radar system but rather a validation to provide confidence to the Range Commander that the asset suitably performs the mission. Therefore to be of practical use, efficient use of time is essential so that the total cost to test is limited appropriately for the intended scope. Secondly, the Point Mugu Sea Test Range is heavily scheduled and therefore, allotting time to perform test validation flights must consider the affects on the limited resources of the range and not conflict with other weapon system testing. Therefore, the profile's test hazard pattern was designed to be small enough to fit in multiple areas of the range, thereby making it possible to simultaneously conduct test operations in one area while performing the validation test in another.

The proposed test will be performed in two parts. Part I will validate the aircraft's autonomous detection capability and Part II will focus on specific mission related functions while under positive control. General flight data will be recorded during both stages to verify aircraft performance. Verification is determined by comparing the data collected with the CRM as it applies to each test part. Tables are provided that explain the elements of test as they relate to each item of the CRM.

Part I, Autonomous Search

During this stage the HSMST will be stationed inside a specified search square with 40 nm sides, but its location will be undisclosed to the test flight crew. The test

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[20] Naval Air Warfare Center Radar Reflectivity Laboratory, "Radar Cross-Section Measurements of the MBAR Rib Target Boat," 4 January 1999.

aircraft will launch, self navigate to the search area (location defined in the test mission brief), and perform a parallel track search as depicted in Figure 9. The search altitude will be 5,000 ft MSL which is based on the typical altitude assigned by the range for aircraft performing this mission.

The parallel track search is a search method designed to produce an evenly distributed search of a known area.[21] The sweep width of this test will be fixed at 20 nm in order to standardize the profile. While sweeping the area the radar operator will develop a surface plot of all targets detected by the radar. The surface plot is a record of the number of radar contacts, contacts course and speed, and contact positions. Radar contacts will be designated and relayed to the range control facility. If necessary to complete the surface plot, the aircraft may perform up to two full sweeps of the area. Once all of the radar contacts detected by the aircraft have been designated, and characterized in terms of position, course, and speed, Part I is complete.

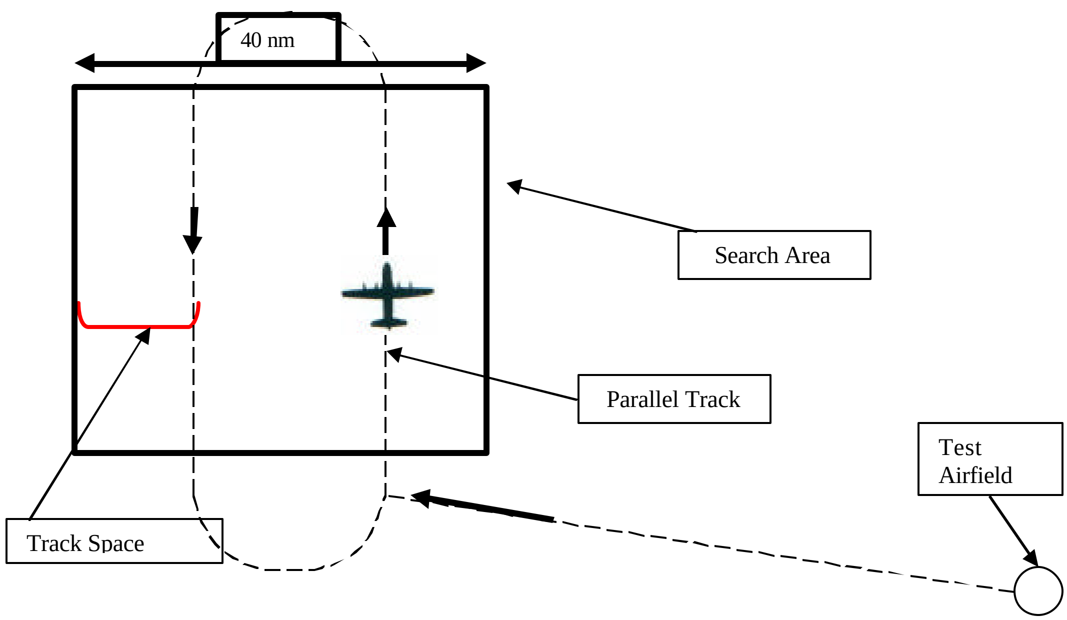


Figure 9. Depiction of Flight Test Part I, Autonomous Search

[21] *Search Theory and Applications*, K. Brian Haley and Lawrence D. Stone, NATO Conference Series Series II, Volume 8, New York, Plenum Press, 1980, 55.

Analysis of Part I Flight Test Data

The test card for recording data from Part I is presented in appendix A, Figure 16. Table 2 describes the relation between the data gathered from the Part I test and specific items of the CRM for validation.

Part II, Directed Search

During Part II, range surveillance will disclose which of the identified contacts the HSMST is; if not previously detected then range surveillance will disclose the HSMST's location. Range surveillance will then direct the test aircraft to a distance 10 nm outside of AREPS predicted maximum detection range (not to exceed 60 nm) from the HSMST. Once in position, range surveillance will direct the HSMST to maintain a heading which presents a 30 to 60 degree aspect to the test aircraft. This aspect should provide a radar return signature on the order of 3 m^2 RCS.

The test aircraft will then be vectored directly toward the HSMST. The radar operator in the test aircraft will record and report to range surveillance first radar contact,

Table 2. Validation of Part I Data versus CRM

CRM #	Data Compared from Part I with CRM Item for Validation
4	The degree of accuracy that the test aircraft autonomously navigates to search box and through test pattern can be directly compared against the ±0.5 NM required by this CRM item.
5	Test aircraft will maintain radio communication with range surveillance during the entire test period. Any loss of communications will be noted.
8	Accurately detecting the HSMST in the first sweep will favorably compare the test aircraft against this CRM item.
9	Same as above
10-13	In building surface plot, the radar operator of the test aircraft will designate multiple radar contacts and report contact location (range bearing, latitude and longitude if system supports) and the contact course and speed. The evaluator can correlate these reports during test with the RSC's surface picture as well as post test with the HSMST's GPS data recording.
14	Radar performance will be validated up to wind/sea state conditions on day of test

first continuous hold, and loss of contact at minimum range. If the test aircraft is unable to detect the target, the RSC will direct the HSMST to turn to present a stern aspect to the test aircraft to increase its radar signature. Once the HSMST is steady on new heading the RSC will reposition the test aircraft outside maximum detection distance and recommence the test run.

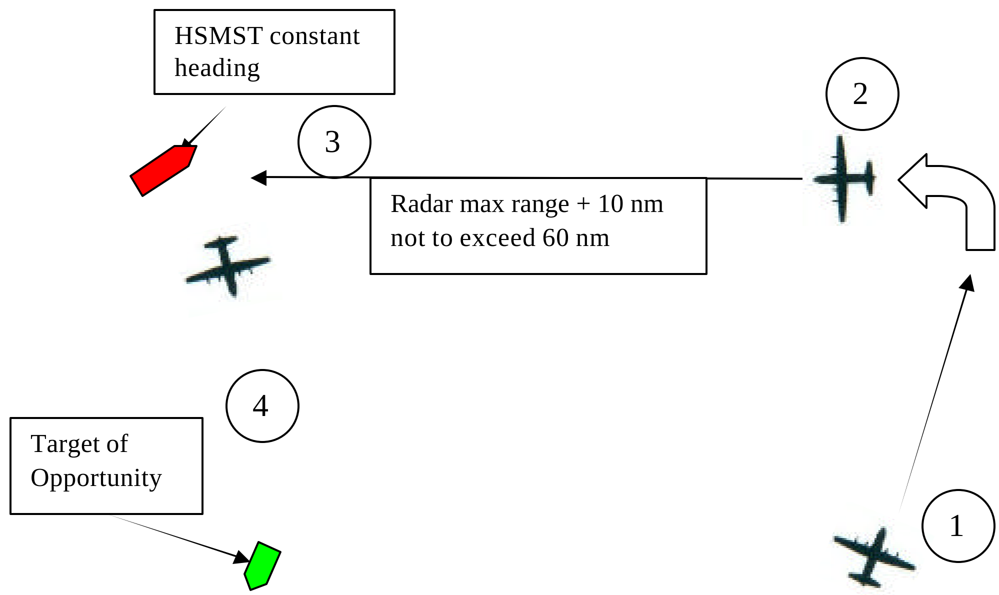
As the aircraft closes to within 10 nm of the HSMST, range surveillance will direct the aircraft under test to establish radio contact with the HSMST on marine VHF/FM channel 16. Once communications are established on channel 16, the test aircraft will direct a channel change to VHF/FM channel 8 and reestablish and confirm acceptable communications on both frequencies. If more time is necessary to complete the communications test, the test aircraft will be directed to orbit within 10 nm of the HSMST.

The test aircraft will then be directed by range surveillance to descend under visual meteorological conditions (VMC) to VID a target of opportunity. It is preferable that a target of opportunity from the Part I flight test be used. The purpose is to demonstrate the test crew's ability to identify a previously unknown target. However if one is unavailable the aircraft should be re-directed to find the HSMST. Once the selected target is visually identified, the crew will record and report the vessel's name, and perform a surface vessel identification in accordance with the Navy Search and Rescue Tactical Information Document (SAR TACAID) manual.[22]. The general flow of the Part II test is presented in Figure 10 with the numbers representing the sequence of actions taking place.

Analysis of Part II Flight Test Data

The test card for recording data from Part II is presented in appendix A, Figure 17. As is Part I, Table 3 describes the relation between the data gathered from the Part II test and specific items of the CRM for validation.

[22] Naval Air Systems Command, *Navy Search and Rescue Tactical Information Document (SAR TACAID)*, NAVAIR A1-SARBA-TAC-00, September 1997.p.6-2-6-5.



1	Aircraft vectored to a maximum of 60 nm from the HSMST
2	Commence inbound run towards the 30-60 degree bow aspect to determine maximum and minimum range
3	Aircraft to HSMST marine FM radio checks (channel 16 and 8)
4	VID of selected target

Figure 10. Depiction of Flight Test Part II, Directed Search Communications, and VID

Table 3. Validation of Part II Data versus CRM

CRM #	Data Compared from Part II with CRM Item for Validation
3	The maximum detection range determined from this test combined with aircraft search speed can be used to analyze the time to clear 20,000 $miles^2$.
5	Test aircraft will maintain radio communication with range surveillance during the entire test period; Any loss of communications will be noted.
6	The capability to communicate with the HSMST over marine band FM frequencies will be demonstrated. Successfully directing a frequency switch demonstrates the capability of communicating directions to targets.
7	A positive VID of a target of opportunity, or the HSMST will directly validate this CRM item.
8	30-60 degrees off bow aspect is considered a reasonable representation of a 3 m^2 RCS target.
9	The first detection of the HSMST will increase confidence in radar's first pass POD. If the aircraft is unable to detect the HSMST in a 30-60 degree off bow aspect this may reduce confidence in its first pass detection capability.
10	Range surveillance can verify position reported either by direct correlation with their own land based radar or post mission analysis with HSMST GPS recorded data.
14	Radar performance will be validated up to wind/sea state conditions on day of test.

Analysis of General Data

The test card for recording general aircraft data from Part I and II is presented in appendix A, Figure 18. Table 4 describes the relation between general data gathered and specific items of the CRM.

Summary

Table 5 presents a summary of the various requirements, which method was used to test them, and the total number of times the requirement is evaluated. The proposed method covers the all of the CRM items, with most items being evaluated multiple times.

Table 4. Validation of General Flight data versus CRM

CRM #	General Data Compared with CRM Items for Validation
1	Taxi, takeoff and landing times can be compared to fuel expended to validate endurance
2	Test aircraft will validate this CRM item by performing Part I and II tests at a Vc of at least 150 KIAS
14	Dependent upon weather conditions on the day of test- Test aircraft should demonstrate capability to operate in IMC conditions

Table 5. Summary of CRM Item Testing

CRM #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Preliminary Requirements Comparison			**X**					**X**	**X**					
Preflight Systems Check					**X**	**X**							**X**	
Flight Test Part I			**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**	**X**	**X**
Flight Test Part II			**X**		**X**	**X**	**X**	**X**	**X**	**X**				**X**
Flight Test General	**X**	**X**												**X**
Analysis	**X**			**X**						**X**	**X**	**X**		
Summary	**2**	**1**	**3**	**2**	**3**	**2**	**1**	**3**	**3**	**3**	**2**	**2**	**2**	**3**

CHAPTER IV. VALIDATION TEST RESULTS REPORTING

This section will describe the method by which the data are processed into a suitable decision tool that the approval authority can use to determine if an aircraft and radar system meets the requirements for range surveillance and clearance. This will take the form of a report of validation test results, presented by the evaluating project test engineer. The report will contain a synoptic scoring of the test aircraft versus the CRM, a recommendation by the evaluator, as well as enclosures for the collected data. An example of the report from this validation is presented in appendix B. The complete package will be submitted for approval via the process explained in chapter III.

An example of the process to create a report of validation test results is provided by application of the data from the flight test program of the C-130 AN/APS-115 modification effort[23]. Where data are missing from the test program, notional numbers have been substituted in order to complete the package. This example will explain the process that results in the report of validation test results for range authorities' review.

Decision Assessment Color Code

Although quantitative data are used to provide an objective assessment of test results, a subjective method of analysis is also needed to support the assessment of these data and rationalize the results. To that end the decision assessment color code (DACC), as presented in Figure 11, will be used to make value judgments relating to the acquired test data and observations as they apply to the satisfaction of the requirements.

[23] Naval Air Warfare Center Weapons Division, "Evaluation of the APS-115 RADAR as Installed in the KC-130F, For the Range Surveillance and Clearance Mission", Report Number RSAT-2005-01-RTR, 30 JAN 2006.

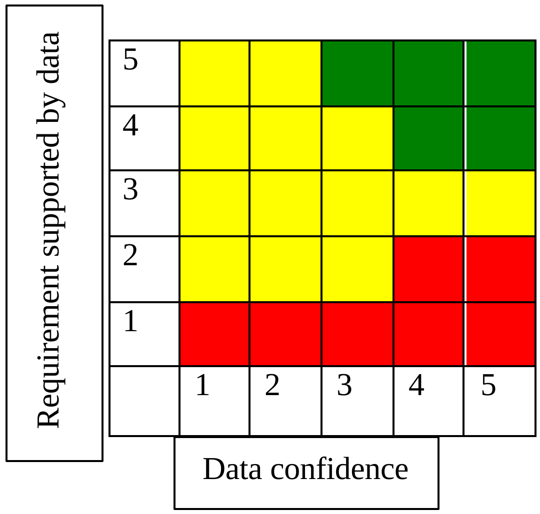


Figure 11. Decision Assessment Color Code

The vertical axis is used to describe the degree to which the data support the conclusion that a specific requirement of the CRM was satisfied. The numbers correspond as follows:

1	2	3	4	5
Not supported	*Somewhat supported*	*Supported*	*Strongly supported*	*Fully supported*

For example, if a requirement were laid out that an individual basketball player make ten free throws in a row, a 5 on the vertical axis would indicate all ten were made. If the player made four of ten free throws, a 2 would be indicated.

The horizontal axis represents the degree to which the evaluator has confidence in the data produced. In our basketball example, if the player performed the free throws outside on a windy day, a poor performance may be attributed to the conditions so the confidence in the validity of the data would be low. On the other hand if the test were repeated ten times on ten different days with a small variation in average result, confidence would be very high that the data accurately represents reality. The numbers of the horizontal axis correspond as follows:

1	2	3	4	5
Not confident	*Some confidence*	*Confident*	*Very confident*	*Fully confident*

The two axes are combined to provide a DACC for each category of the CRM. The color code is assigned by the evaluating project test engineer. Green would indicate that the aircraft met the particular criteria. Yellow indicates a medium level of capability and may or may not need more investigation. For example, if a test were to be conducted at the extreme range of the envelope with a large hazard pattern to clear, an aircraft that scored a yellow in the endurance category might be disqualified, or might be qualified with restrictions. That same aircraft may then be suitable for a near shore test with a small hazard pattern. Red would indicate a serious deficiency either in performance demonstrated or in the confidence of the data. In the later case, range authorities may consider reevaluating the parameter in question to determine if a more favorable scoring is appropriate.

Example of DACC Data Processing

When an DACC has been assigned to each category of the CRM, the project engineer will condense them into one table as presented in Table 6. The coordinates of each color will be included in an effort to provide the rationale behind the rating. This table gives the approval authorities a visual means to support a decision which is data driven and takes into account a qualitative assessment of the variables that may have affected the test results.[24] The following paragraphs contain an explanation of how the summary table presented was created.

[24] Maarten W. Bos , Rick B. van Baaren, A. J. Dijksterhuis, and Loren F. Nordgren, "On Making the Right Choice: The Deliberation-Without-Attention Effect", Science, 17 February 2006, vol 311, p 1005-1007.

Table 6. CRM versus DACC Summary

CRM #	Validation Method	Narrative	ACC
1	Flight Test/Analysis	C-130 Manuals support endurance of 10 + hrs submitted on data sheet, Test aircraft used 4,800 lbs/hour during 3.2 hour mission representative flight test which correlates to approximately 8.75 endurance with no internal tank installed (12.5 with internal tank).	5,5
2	Flight Test/Analysis	C-130 easily meets requirement. Crew procedures indicate that 180 KIAS is the preferred search speed, however accelerations to 250 KIAS were demonstrated which are enhancing for prosecuting targets at distance.	5,5
3	Preliminary Requirements Comparison/ Flight Test/Analysis	Using a 60 nm sweep width which is validated by the AREPS model, and the maximum detection range demonstrated in test, the C-130 could clear a 20,000miles ^{2} box in approximately 2 ¼ hours. Further correlation of this is evidence by the sweep of a 1600 nm test box with a complete surface plot calculated in 21 minutes.	4,4
4	Flight Test/Analysis	C-130 navigated with negligible error to a predetermined search area and accurately through the search course defined. Consistently navigated well within ±0.5 nm accuracy required. The C-130 as tested, utilized, dual INS systems with embedded GPS. Additionally, although less accurate, dual TACAN/VOR could be used.	4,5
5	Preflight Systems Check/Flight Test	Dual UHF/VHF demonstrated in the ground. During flight test aircraft maintained dual frequency communication with range surveillance and air traffic control throughout test period. No problems noted.	5,5
6	Preflight Systems Check/Flight Test	C-130 did not have organic marine band capability. Workaround utilized hand held ICOM radios which were demonstrated on the ground up to all required frequencies. Because the handhelds are broadcast through the glass of the flight station they performed poorly when the HSMST was at the stern of the aircraft. Radios are workable but with some loss of communications capability.	4,3
7	Flight Test	During test the C-130 descended to 500 ft and identified a target of opportunity. The aircraft was identified by name, type, and characteristics as well as estimated course and speed. Additionally C-130 aircraft are used by the U.S. Coast Guard as a search an rescue asset, a mission which requires VID, and therefore can be considered previously certified by a government agency for VID.	4,5
8	Preliminary Requirements Comparison/ Flight Test	AREPS simulation suggests target acquisition out to ˜22nm. In practice the HSMST was detected multiple times during flight test out to 50 nm. Data confidence lowered due to poor correlation between HSMST and specified target RCS.	3,4
9	Preliminary Requirements Comparison/ Flight Test	AREPS simulation supports this conclusion. C-130 detected the HSMST on first pass during two different tests. Data confidence lowered due to poor correlation between HSMST and specified target RCS, and limited number of test passes.	3,4

Table 6 Continued

CRM #	Validation Method	Narrative	ACC
10	Flight Test, Analysis	C-130 performed an airborne calibration test against fixed target of known position (Begg rock) and accurately identified multiple targets of opportunity and the HSMST during the entire flight test. The accuracy level of ±0.5 nm could not be proved at longer ranges due to beam width variation however, the radar performance was more than adequate to determine if a target would foul the hazard pattern.	4,4
11	Flight Test, Analysis	C-130 multiple times presented accurate target course (±5 degrees) data both for targets of opportunity and the HSMST. The radar determined course was compared real time with ground tracking stations as well as post mission with HSMST GPS data.	4,4
12	Flight Test, Analysis	C-130 multiple times presented accurate target speed (±3 knots) data both for targets of opportunity and the HSMST. The radar determined course was compared real time with ground tracking stations as well as post mission with HSMST GPS data.	4,4
13	Preflight Systems Check/Flight Test	AN/APS-115 able to process multiple contacts according to manufacturers specs. Radar operator demonstrated system during ground test. During flight test C-130, successfully tracked 5 targets (HSMST and 4 targets of opportunity).	4,5
14	Flight Test, Analysis	C-130 is a proven all weather aircraft. System performed well with the following ambient conditions. Surface winds (average 9 knots) and Sea State estimated at 3 Beaufort scale.	3,4

Endurance(CRM # 1)

Endurance can be calculated from aircraft publications. However, flight test is useful in determining the validity of the published endurance charts as compared to mission representative operations. The actual search speed, fuel expended during climbs and descents, as well as speed changes during VID can not be accurately interpolated by use of aircraft performance charts alone. Therefore flight test correlation is a valuable tool for enhancing confidence in the endurance predictions made of the proposed aircraft.

Cruise Airspeed (CRM # 2)

Cruise airspeed is one of the easier parameters to check. Virtually all proposed aircraft will have some established history regarding maximum, minimum and endurance airspeeds and this CRM can probably be determined with high confidence prior to flight.

However, if a question exists, the flight test can be used to validate speed by monitoring the average search speed from the RSC, or onboard evaluator as applicable.

Search Speed (CRM #3)

The degree to which an aircraft meets this requirement is dependent on the maximum range of the radar and the aircraft search speed. The raw data from the C-130 aircraft test indicate that the maximum range for detecting the HSMST was 50 nm. As will be explained in a later paragraph, the AREPS model predicted approximately a 22 nm maximum range. A 30 nm range was assumed as a middle ground between the two maximum ranges and was chosen for both simplicity and to err on the conservative side. Using a search speed of 180 KIAS and the example 20,000 $miles^2$ search area from Figure 3, the following assumptions and calculations were made. A 30 nm maximum range could be used to determine a sweep width of 60 nm. This is supported both by the AREPS model and well within the range demonstrated by flight test. A 60 nm sweep with would require 3 track runs of the proposed box. That would require covering a total distance of no more than 400 nm which under no wind would equate to 2 ¼ hours to cover the entire 20,000 $miles^2$. Figure 12 is a visual presentation of the search path described. The time to create a surface plot of the 1600 mi^2 test area in the Part I flight test can be used as order of magnitude supporting evidence.

Navigation(CRM #4)

Modern aircraft almost universally incorporate GPS technology for very accurate navigation and as such this criterion of the CRM, although important, is not expected to produce many failures. Flight test Part I will confirm capability of aircraft (and aircrew) to navigate with precision to a predetermined start point. The data package may comment on type of systems incorporated and number and quality of redundant systems.

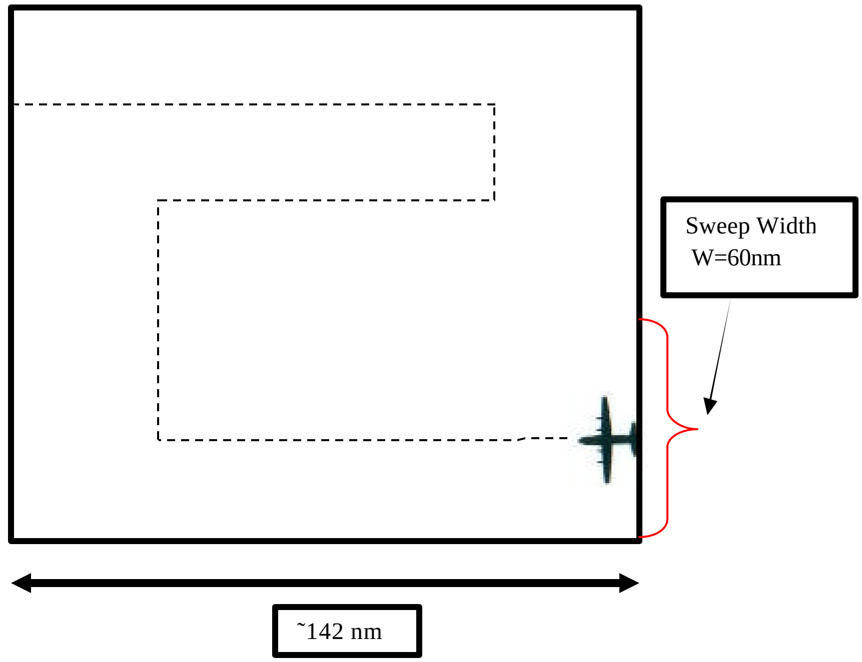


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Figure 12. Search Area Determination Rationale

<u>Communications(CRM# 5 and 6)</u>

Communications are assessed primarily through qualitative evaluation. The radios will be checked during preflight systems check for functionality as well as frequency range covered. Comments can also be made on quality and number of radios employed.

<u>Visual Identification (VID) (CRM # 7)</u>

This criterion could be considered more of a crew capability requirement than an aircraft capability. The validation supports the mission capability.

<u>Radar Detection (CRM # 8-9)</u>

Compliance with these CRM criteria are modeled through the AREPS computer program, and validated through flight test. Figure 13 and Figure 14 are the AREPS prediction of the AN/APS-115 radar versus a 3 m^2 RCS target. The two graphs are to account for two

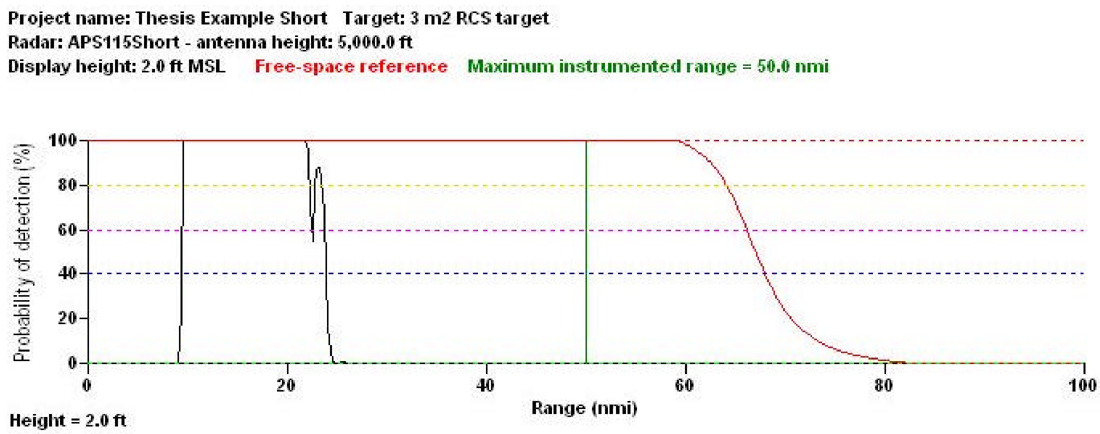

Figure 13. AN/APS-115 Short Pulse Mode versus 3m^2 RCS Target

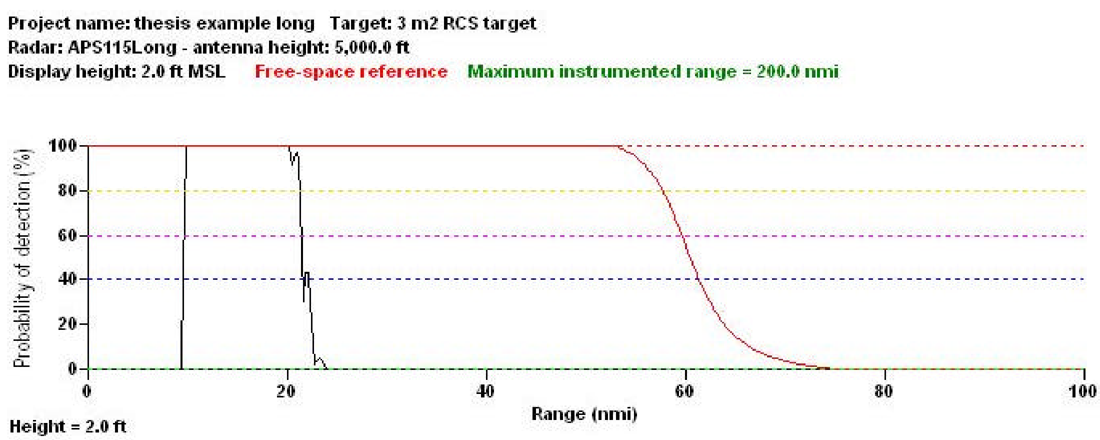

Figure 14. AN/APS-115 Long Pulse Mode versus 3 m^2 RCS Target

different operating modes (short and long pulse respectively) of the radar. The operator can switch back and forth between modes as deemed necessary to present the best surface picture. Both modes predicted similar results for the small target. Actual flight test results extended the range out to 50 nm. There are many reasons for a discrepancy in the data, the most significant being that the HSMST is not a uniformly distributed 3 m^2 RCS target. Further, even a uniformly distributed target would vary based on motion sea state, forward motion of the boat and the wake it creates.

Target Accuracy (CRM #10)

Flight test data gathered can be compared real time and during post mission analysis to determine the accuracy of radar. The accuracy level described by the CRM is extremely difficult to prove because of the inherent error in recording locations, aircraft position.

Radar Processing (CRM # 11-12)

As the radar operator tracks various contacts over time, a solution for speed and course can be determined. Some radar systems will automatically solve for this product while others rely on the operator to manually solve for the course speed. The radar operator's solutions can be compared both real time and during post mission analysis to determine accuracy of the track. The most useful data is the track of the HSMST which is a target of the smallest expected type and is controlled in that its speed and course can be commanded by the test operations conductor and are recorded on its onboard GPS system.

Radar Processing (CRM # 13)

The capability to label and maintain multiple contacts is a system specific issue which can be demonstrated to the project test engineer during the preflight systems check, and proven during the first part of flight test when the surface plot is created.

Weather/Surface Conditions(CRM#14)

This criterion is not a controlled parameter and is limited to the conditions on the day of the test. Evaluators can analyze aircraft based on historical performance as well as document performance as tested.

Summary

The elements described above will be compiled into one table and submitted with data input sheets, supporting data, and preflight systems check and flight test cards. The synoptic summary will be the archival record which can be referenced and used as a starting point for further tests as necessary.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In the opinion of the author, it is possible to develop a single generic method to validate a proposed aircraft for the range surveillance and clearance mission. Because no standardized method currently exists to provide this type of validation, the method proposed is an improvement over the existing approval system. The proposed method presents a standardized means for qualifying an aircraft for the range surveillance and clearance mission. Additionally, the report of validation test results provides a resource by which an approval authority can confidently accept an aircraft for use in this mission, and one which can be archived for later reference.

However, during this conduct of this study, the following limitations were discovered that can affect the results of this process.

1. Target detection is limited to test day environmental conditions which could potentially skew results.
2. The HSMST can only be reliably characterized in terms of radar cross section from specific angles and with no motion. Depending on the atmospherics and sea state, capable radars may be unable to detect the HSMST or substandard radars may show better than expected performance.
3. Performance of an aircraft radar system is highly dependent on capable and highly trained operators. Poor test results may be attributed to poor system operator performance.
4. Existing range clearance instructions contain requirements that are designed for very large test hazard patterns. These requirements have the effect of excluding aircraft which would be very suitable for the more typical range clearance missions that cover on the order of 1/20th the 20,000 $miles^2$ detailed in the CRM.

Recommendations

The Navy's national range authority, NAVAIR 5.2 should consider creating a standardized policy to include the approved method for validating range surveillance and clearance aircraft as described in this paper. The instruction should clearly define organizational roles and responsibilities as well as the reporting criteria, signature authority, and archiving instructions.

A study should be conducted to investigate ways to mitigate some of the limiting factors of the test method proposed by this thesis. For example, a restriction that places limits on test day sea state and weather conditions could improve the accuracy of the assessment of radar performance. Another example would be a requirement that the radar operator of the candidate system have current experience in the surface surveillance environment; preferably with the system under test. Lastly, a revision of the requirements should be considered to reflect the typical test patterns which do not require searching large areas. This would allow for the consideration of assets with lesser endurance but capable radar systems such as Navy helicopters.

Additionally, the author recommends the study of a future improvement to this proposed method which would create a database of potential range surveillance and clearance aircraft. Query logic could be incorporated which would ask for the parameters of a specific mission (area of the hazard pattern, time of event etc.). Using these parameters the data base could provide a list of all the aircraft types suitable for the mission. The Range Commander or operations conductor could then select the most appropriate option based on cost versus performance or availability.

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APPENDICES

APPENDIX A. TEST DATA CARDS

Preflight Systems Check Data Card			
Date:	Evaluator:	Aircraft/System Under Test	Control Number:

Evaluate the Following	v When Complete	Data Required :	Comments: Make qualitative comments as necessary
Turn radar system on, observe BIT checks if applicable		Note clock time system turned on:_________	
Observe operator performing normal procedures to make system ready for use.		Note clock time system is ready for use:_________	
Conduct system familiarization for evaluator.		None	
*** Note: Prior to radiating for ground test, ensure ground personnel and equipment are at the minimum required distance for the system being tested**			
Observe all selectable radar modes, scan rates. Secure radar when complete.		None	
Radio checks. At a minimum check primary, backup range surveillance frequency and VHF/FM marine channel 16 and 8			
Other?:			

This system has displayed adequate performance to proceed to flight test:	______________________________ **Evaluator Signature**

Figure 15. Preflight Systems Check Data Card

Part I Flight Test Data Card
Autonomous Search Surface Plot

Performing parallel search pattern defined by → REPORT ALL CONTACTS TO RANGE SURVEILLANCE	Latitude	Longitude	**Time to complete surface plot**
	__°__._ N	**__°__._ W**	**Record clock time**
	__°__._ N	**__°__._ W**	**Commenced:____________**
	__°__._ N	**__°__._ W**	**Completed:______________**
	__°__._ N	**__°__._ W**	

Contact Time		Contact Time	
Position (range/bearing)		Position (range/bearing)	
Course/Speed		Course/Speed	
Designation		Designation	

Contact Time		Contact Time	
Position (range/bearing)		Position (range/bearing)	
Course/Speed		Course/Speed	
Designation		Designation	

Contact Time		Contact Time	
Position (range/bearing)		Position (range/bearing)	
Course/Speed		Course/Speed	
Designation		Designation	

Figure 16. Part I Flight Test Data Card

<table>
<tr><th colspan="3">Part II Flight Test Data Card
Directed Search</th></tr>
<tr><th>Max/Min radar detection</th><th>Data Required</th><th>Comments</th></tr>
<tr><td>Report/record first detection of HSMST</td><td>Time:______________
Range:_____________
Bearing:____________</td><td></td></tr>
<tr><td>Report/record continuous HSMST radar return</td><td>Time:______________</td><td></td></tr>
<tr><td>Report/record loss of contact at min range</td><td>Time:______________
Range:_____________
Bearing:____________</td><td></td></tr>
<tr><td colspan="3">COMMUNICATIONS TEST</td></tr>
<tr><td>Establish communications with HSMST on FM Channel 16</td><td>Report clarity in terms of loud and clear from 0-5</td><td></td></tr>
<tr><td>Switch HSMST to FM Channel 8
Once data recorded, comm test complete</td><td>Report clarity in terms of loud and clear from 0-5</td><td></td></tr>
<tr><td colspan="3">VID contact</td></tr>
<tr><td>When directed, proceed to contact designated by range surveillance and descend VMC to VID target</td><td>Vessels
Name:_____________

Estimated course/speed:

_________________________</td><td></td></tr>
<tr><td>Vessel Type (circle):

Merchant Fishing

Sailboat Powerboat</td><td colspan="2">Notes on contact characteristics:</td></tr>
</table>

Figure 17. Part II Flight Test Data Card

General Flight Test Data Card

Date:	Evaluator:	Aircraft/System Under Test	Control Number:

HSMST Call Sign	Range Control Frequencies Primary___________ Backup_______________		ATIS__________ Runway in Use___________ Reported Winds/Temperature

General:	**Mission Notes:**
Takeoff, when ATC hands off to range control, climb to 5,000 ft MSL and proceed to search area. Search Track begins at: Latitude______________________ Longitude_____________________	

Procedure	**Data Required**	**Comments**
Start Up	Note Time: Fuel Onboard:	
Takeoff	Note Time	
Enroute	Note: Sea State:	
Landing	Note Time:	
Shutdown	Note Time: Note Fuel onboard	

Figure 18. General Test Flight Data Card

APPENDIX B. EXAMPLE REPORT OF VALIDATION TEST RESULTS

Date

From: Gish, J.G. Project Engineer 521100E
To: Appropriate Final Authority Name Title

Ref: (a) NAVAIR 5.2 INST XXXX.X
Encl: (1) Input Data Sheet (Control Number XXXX)
(2) Supporting Data
(3) Ground and Flight Test Cards

Subj: REPORT OF VALIDATION TEST RESULTS OF THE NC-130F, FOR THE RANGE SURVEILLANCE AND CLEARANCE MISSION

1. Between (x-x Days Month Year), analysis, ground and flight test were performed to determine the suitability of the NC-130F (Bureau Number 168563) to perform the range surveillance and clearance mission. Specifically the aircraft and system were tested to determine compliance with the capabilities requirements delineated in reference (a). Table 1 is a summary of the findings**.**

Table A 1. Summary Findings

CRM #	Validation Method	Narrative	ACC
1	Flight Test/Analysis	C-130 Manuals support endurance of 10 + hrs submitted on data sheet, Test aircraft used 4,800 lbs/hour during 3.2 hour mission representative flight test which correlates to approximately 8.75 endurance with no internal tank installed (12.5 with internal tank).	5,5
2	Flight Test/Analysis	C-130 easily meets requirement. Crew procedures indicate that 180 KIAS is the preferred search speed, however accelerations to 250 KIAS were demonstrated which are enhancing for prosecuting targets at distance.	5,5
3	Preliminary Requirements Comparison/ Flight Test/Analysis	Using a 60 nm sweep width which is validated by the AREPS model, and the maximum detection range demonstrated in test, the C-130 could clear a 20,000miles ^{2} box in approximately 2 ¼ hours. Further correlation of this is evidence by the sweep of a 1600 nm test box with a complete surface plot calculated in 21 minutes.	4,4
4	Flight Test/Analysis	C-130 navigated with negligible error to a predetermined search area and accurately through the search course defined. Consistently navigated well within ±0.5 nm accuracy required. The C-130 as tested, utilized, dual INS systems with embedded GPS. Additionally, although less accurate, dual TACAN/VOR could be used.	4,5
5	Preflight Systems Check/Flight Test	Dual UHF/VHF demonstrated in the ground. During flight test aircraft maintained dual frequency communication with range surveillance and air traffic control throughout test period. No problems noted.	5,5
6	Preflight Systems Check/Flight Test	C-130 did not have organic marine band capability. Workaround utilized hand held ICOM radios which were demonstrated on the ground up to all required frequencies. Because the handhelds are broadcast through the glass of the flight station they performed poorly when the HSMST was at the stern of the aircraft. Radios are workable but with some loss of communications capability.	4,3
7	Flight Test	During test the C-130 descended to 500 ft and identified a target of opportunity. The aircraft was identified by name, type, and characteristics as well as estimated course and speed. Additionally C-130 aircraft are used by the U.S. Coast Guard as a search an rescue asset, a mission which requires VID, and therefore can be considered previously certified by a government agency for VID.	4,5
8	Preliminary Requirements Comparison/ Flight Test	AREPS simulation suggests target acquisition out to ~22nm. In practice the HSMST was detected multiple times during flight test out to 50 nm. Data confidence lowered due to poor correlation between HSMST and specified target RCS.	3,4
9	Preliminary Requirements Comparison/ Flight Test	AREPS simulation supports this conclusion. C-130 detected the HSMST on first pass during two different tests. Data confidence lowered due to poor correlation between HSMST and specified target RCS, and limited number of test passes.	3,4

Table A 1 Continued

CRM #	Validation Method	Narrative	ACC
10	Flight Test, Analysis	C-130 performed an airborne calibration test against fixed target of known position (Begg rock) and accurately identified multiple targets of opportunity and the HSMST during the entire flight test. The accuracy level of ±0.5 nm could not be proved at longer ranges due to beam width variation however, the radar performance was more than adequate to determine if a target would foul the hazard pattern.	4,4
11	Flight Test, Analysis	C-130 multiple times presented accurate target course (±5 degrees) data both for targets of opportunity and the HSMST. The radar determined course was compared real time with ground tracking stations as well as post mission with HSMST GPS data.	4,4
12	Flight Test, Analysis	C-130 multiple times presented accurate target speed (±3 knots) data both for targets of opportunity and the HSMST. The radar determined course was compared real time with ground tracking stations as well as post mission with HSMST GPS data.	4,4
13	Preflight Systems Check/Flight Test	AN/APS-115 able to process multiple contacts according to manufacturers specs. Radar operator demonstrated system during ground test. During flight test C-130, successfully tracked 5 targets (HSMST and 4 targets of opportunity).	4,5
14	Flight Test, Analysis	C-130 is a proven all weather aircraft. System performed well with the following ambient conditions. Surface winds (average 9 knots) and Sea State estimated at 3 Beaufort scale.	3,4

2. As project engineer for this test I was impressed with the AN/APS-115 radar's overall performance, as installed in the C-130. I recommend approval of the NC-130F as a range surveillance and clearance asset with no restrictions.

____
signature

VITA

Shawn M. Disarufino was born in Phoenix, Arizona on September 2 1969 where he was reared. He graduated from Scottsdale Christian Academy High School in 1987. He was given an appointment to the United States Naval Academy. In 1992 he graduated with merit with a B.S. in Naval Architecture and was given a commission as Ensign in the U.S. Navy. After attending flight school in Pensacola, Florida and Corpus Christi, Texas he was designated a Naval Aviator in 1994. He then went on to an operational tour flying H-46 helicopters in Guam. After an assignment as a primary flight instructor in the T-34C, he transitioned to the C-130 as a member of Fleet Logistic Support Squadron Five Five (VR 55), in Point Mugu, California. From there, LCDR Disarufino attended the U.S. Naval Test Pilot School from January through December 2003. Following graduation he served as range support project officer for Air Evaluation Test Squadron Three Zero (VX-30). He is currently assigned to the multi-mission helicopter program office (PMA-299) in Patuxent River, MD.