Electronic Trajectory Measurements Group

DOCUMENT 267-19

DEFINITION OF INSTRUMENTATION RADAR

ABERDEEN TEST CENTER
DUGWAY PROVING GROUND
ELECTRONIC PROVING GROUND
REAGAN TEST SITE
REDSTONE TEST CENTER
WHITE SANDS TEST CENTER
YUMA PROVING GROUND

NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION PATUXENT RIVER
NAVAL AIR WARFARE CENTER WEAPONS DIVISION CHINA LAKE
NAVAL AIR WARFARE CENTER WEAPONS DIVISION POINT MUGU
NAVAL SURFACE WARFARE CENTER DAHLGREN DIVISION
NAVAL UNDERSEA WARFARE CENTER DIVISION KEYPORT
NAVAL UNDERSEA WARFARE CENTER DIVISION NEWPORT
PACIFIC MISSILE RANGE FACILITY

30TH SPACE WING
45TH SPACE WING
96TH TEST WING
412TH TEST WING
ARNOLD ENGINEERING DEVELOPMENT COMPLEX

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

This page intentionally left blank.

DOCUMENT 267-19

DEFINITION OF INSTRUMENTATION RADAR

December 2019

Prepared by

Electronic Trajectory Measurements Group

Published by

Secretariat
Range Commanders Council
U.S. Army White Sands Missile Range
New Mexico 88002-5110

This page intentionally left blank.

Table of Contents

Tables

This page intentionally left blank.

Preface

This document introduces a definition for a category of radar systems used by the Department of Defense (DoD) ranges of the Major Range and Test Facility Base (MRTFB).

This stand-alone document was prepared for the Range Commanders Council through the Electronic Trajectory Measurements Group (ETMG). For questions regarding this document, please contact the Range Commanders Council Secretariat office.

Secretariat, Range Commanders Council
ATTN: TEWS-RCC
1510 Headquarters Avenue
White Sands Missile Range, New Mexico 88002-5110
Telephone: (575) 678-1107, DSN 258-1107
E-mail: usarmy.wsmr.atec.list.rcc@mail.mil

This page intentionally left blank.

Acronyms

DoD	Department of Defense
I&Q	in-phase and quadrature
MRTFB	Major Range and Test Facility Base
RCS	radar cross section
SUT	system under test
TSPI	time-space-position information

This page intentionally left blank.

1. Purpose

Over the past few years the DoD Major Range and Test Facility Base (MRTFB) ranges have been in the process of acquiring new/recapitalized radars for the range. The ranges refer to the radars used for the purpose of data acquisition as instrumentation radars. During the process of acquiring new radars, the ranges were asked various questions. A few of the most recurring questions were, “What is an instrumentation radar?” and “Why can’t a tactical radar be used?” When the ranges attempted to answer these questions, it was found that they were hampered by the lack of a true definition for an instrumentation radar.

This document will aid in defining the instrumentation radar category used by the MRTFB ranges. It will also provide a definition along with characteristics, examples, and some comparisons with other radar categories.

2. Definition

The first thing that needs to be defined when creating a definition for an instrumentation radar is the word ‘instrument.’ An instrument, at least in this context, is:

- A tool or implement; especially one for delicate or scientific work.
- A measuring device used to gauge the level, position, speed, etc., of something; especially a vehicle, aircraft, or munition.

While discussing what an instrumentation radar is, it became rather apparent that multiple definitions are needed depending on the audience.

Below are two definitions: “Elevator” and “General.” The “Elevator” definition is intended for discussions with senior officials that are as short as the duration of an elevator ride. The “General” definition is longer and occurs during more technical discussions.

a. Elevator: An instrumentation radar designed specifically for technical and operational test and evaluation activities where accuracy and safety requirements are needed for configuration flexibility, repeatability, reliability, and extremely accurate and precise test data.
b. General: A radio frequency based measurement system that, utilizing **RA**dio **D**etection **A**nd **R**anging (RADAR) principles, has the inherent capability to provide spatial, temporal, inverse synthetic aperture radar imagery, and/or phenomenological test data of targets and surrounding environments. The test data produced characteristically has qualities of high resolution and accuracy; and a nature of low uncertainty in.

The supporting material in this document is intended to explain what an instrumentation radar is and how it compares to other radar categories.

3. Characteristics

Instrumentation radars are defined by many characteristics that make them different than other radar categories; however, the group thought it was important to single out one important characteristic: no one single radar technology can measure everything about a test object. This is important due to the diverse test missions that the MRTFB ranges perform every day.

Below is a list of other characteristics. It is not necessarily an all-inclusive list and is not in any particular order, but it is a good start in defining the special areas that an instrumentation radar needs to perform its mission.

Instrumentation radars …

- are sophisticated measurement instruments;
- are noninterfering with the system under test (SUT);
- measure something about a SUT;
- can be grouped in many ways. (i.e., power output, expected range, families, or munition size);
- have well-characterized system measurement uncertainties;
- measure target trajectories with extreme absolute accuracy (a typical threshold accuracy would be 10 times the trajectory accuracy reported by the SUT);
- utilize multiple tracking techniques;
- time tag data, and provide synchronized operation;
- provide input to the safety solution;
- have the capability to cue and to be cued by other range instrumentation;
- record raw measurement data for postmission analysis (including the entire scene, not just the main target tracks);
- have configurable operator interfaces that can be adapted to the mission and can be changed during the mission;
- are typically more concerned about global coordinate systems instead of relative radar coordinate systems;
- produce customizable engineering unit data to operators and analysts, such as plots or tabular data displaying:
    - range vs. time
    - radial velocity vs. slant range
    - frequency vs. time
    - range vs. height
    - radial velocity vs. time in relation to the weapon or radar
    - drag vs. Mach
    - radial acceleration, and
    - signal to noise;
- do not necessarily need to follow military standards;
- can capture data relative to trigger events;
- typically have unclassified hardware and software components;
- track all types of objects (instrumentation radars are not designed for one specific type). Examples of these targets can be anything from:

- a 5.56-mm small arms ammunition to a 155-mm artillery shell
- small rockets to large intercontinental missiles such as rocket-propelled grenades
- tube-launched, optically tracked, wire-guided missiles; Standard Missile-3, terminal high-altitude area defense missiles, Patriot missiles, etc.
- space-launched vehicles, unmanned aerial vehicles, aircraft, payload drops, or ordnance releases
- low-flying high- and low-speed objects
- closely spaced objects
- small and large objects in the same field of view;

* feed analysis tools to extract detailed information (as listed below), including performance measures, from the recorded raw measurement data;
  - time-space-position information (TSPI), drag, acceleration, spin, miss distance, radar cross section (RCS), impact prediction, event times, target acquisition/interaction, and signature analysis
  - booster performance, parts separation, debris tracking, intercept, kill assessment, observation of fratricide of objects, wing deployment, parachutes, and object characterization
  - high-resolution radar imagery that can characterize post-engagement debris to sense debris cloud growth, estimate particle size and velocities, and measure wind drift
  - define impact points to support range safety analysis model validation, and
  - any other characteristic of the target's phenomenology;
* are typically optimized to their specific measurement role such as continuous-wave Doppler vs. pulsed Doppler vs. RCS measurement. (This characteristic directly aligns with the statement in the above paragraph saying that no one radar technology can measure everything. A real-life example is that an FPS-16 radar isn't equivalent to an SPS Mark V RCS radar. Each radar technology provides specific information about a target and the data produced by each radar, when combined, allows us to assess the SUT's performance.);
* are capable of producing not only TSPI, but calibrated signature and inverse synthetic aperture radar imagery data and characterization of non-instrumented objects; and
* produce state vectors that support rapid prediction of impact point for retrieval of classified or sensitive parts of systems under test and launch systems.

4. Instrumentation Radar Examples

To help with descriptions, some instrumentation radar examples that the MRTFB ranges own are listed in Table 1. Again, this is not an all-inclusive list, but a sample of some of the types.

Table 1. Instrumentation Radar Examples

Instrumentation Radars Utilizing Military Radar Pedestals	Commercial-off-the-shelf (COTS)/Modified COTS	Custom
FPS-16	BAE RIR-980	TA MTS
MPS-39 (MOTR)	BAE DRX-4	COSIP
MPS-25	Weibel MFTR series	Dynetics MRS
MPQ-33	Weibel MSL series	
FPS-134	Weibel SL series	
FPQ-14	Infinition BR series	
TPQ-18	Star Dynamics DSR-1	
FPQ-17	BAE RULE	
	ROTR	
	BAE TRRM	
	ROSA	
	ROSA II	

5. Category Comparison

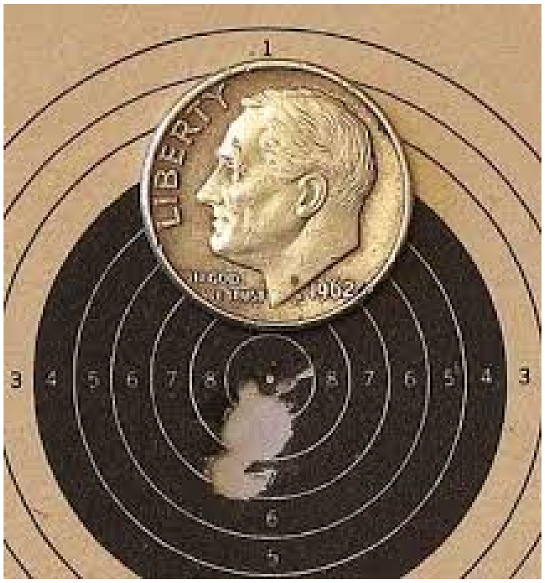
One question received most often is, “Why can’t a tactical radar be used as an instrumentation radar?” The best way to compare these two specific radar categories would be through an analogy and a comparison matrix. For clarification, it is possible that a tactical radar could be used as an instrumentation radar; however, in our experience and analysis, a dedicated instrumentation radar performs better for the MRTFB’s mission.

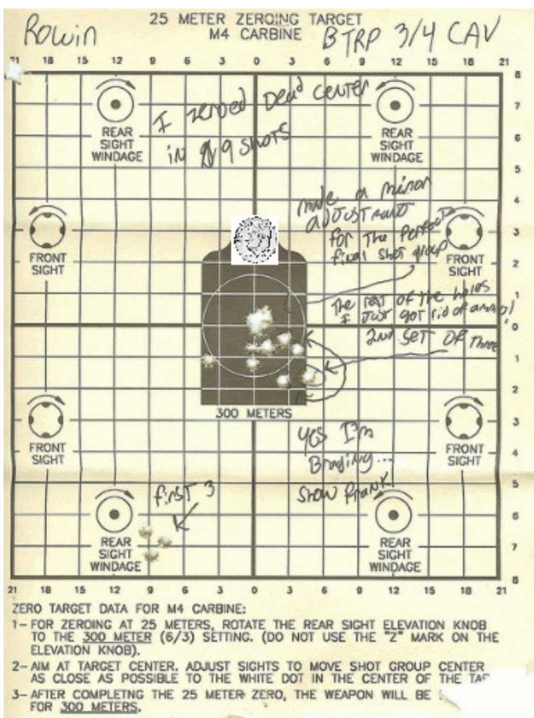
a. Analogy #1. This analogy compares the Olympic match rifle to the M4 Carbine rifle as shown in Table 2. It is used to highlight the instrumentation radar’s ability for extreme absolute accuracy, characterized as a sophisticated measurement instrument with its parameter tunability and system optimization to its role. The match rifle is comparable to the instrumentation radar due to its almost endless adjustments and its need to be extremely accurate in competition. The M4 is a great general-use weapon that doesn’t need the pinpoint accuracy of the match rifle. It only needs to be a close equivalent. The M4 has adjustments, but not nearly as many as the match rifle.

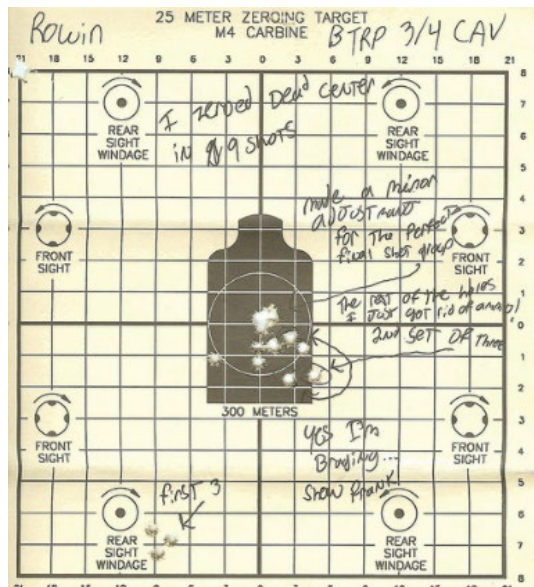
Table 2. Analogy #1	
Instrumentation	**Tactical**
Olympic Match Rifle	M4 Carbine
	

b. Analogy #2. This analogy compares a 10-m match rifle target to a 25-m M4 zeroing target. The zeroing target is printed on standard letter-sized paper. The match rifle target is only 45.5 mm in diameter with a 0.5-mm 10 ring. For added comparison, a dime (that has a diameter of 17.91 mm) is superimposed on the 25-m target to show that it is roughly the same size as the head on the silhouette. The instrumentation radar's ability to have extreme absolute accuracy is demonstrated when the SUT is able to shoot at least 10 rounds grouped through a hole roughly 2 mm in size.

This analogy is also used to highlight the instrumentation radar's ability to have its system measurement uncertainties well characterized; especially when compared to an SUT like the match rifle. It also emphasizes the radar being characterized as a sophisticated measurement instrument. In Table 3, the leftmost picture depicts the match rifle's ability to shoot multiple rounds into an area less than 0.25 inches.

<table>
<tr><th colspan="2">Table 3. Analogy #2</th></tr>
<tr><th>Instrumentation</th><th>Tactical</th></tr>
<tr><td>




</td><td>


</td></tr>
</table>

c. Characteristic Comparison

Tables 4 through 13 illustrate various characteristics of instrumentation radars and compare them against tactical radars.

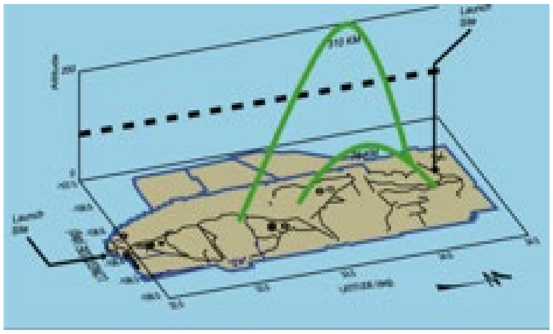
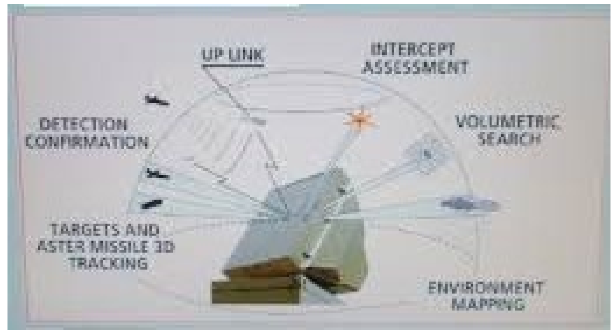
Table 4. Operational Scenario/Purpose & Mission Planning	
Instrumentation	**Tactical**
	
Operational scenario is fully known via test plan.	Operational scenario is typically unknown except for general threat type and axis.
Origin and termination locations, intended flight path and potential deviations typically planned in advance.	Origin location and intended termination generally unknown.
Allows for optimization of radar placement, suggest or allow change of waveforms and tracking assignments during track.	

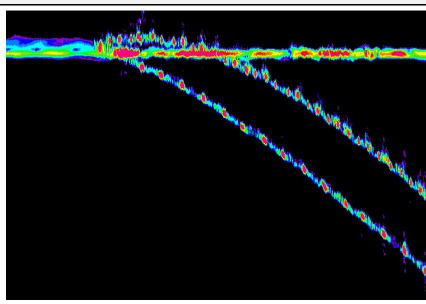
Table 5. Search Capability and Search While Tracking	
Instrumentation	**Tactical**
	
Can search for object in narrow area including separating objects or debris.	Rapid wide-area search.

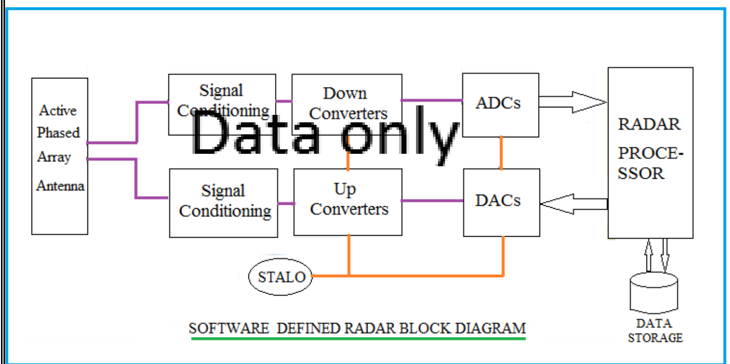
Table 6. Support Fire Control Solution	
Instrumentation	**Tactical**
	 
Not Required. Radar may determine deviations in flight path and calculate updates to prediction.	Primary Purpose. May also predict flight path and direct return fire.

Table 7. Real-Time Target Scene Discrimination/Performance Measures

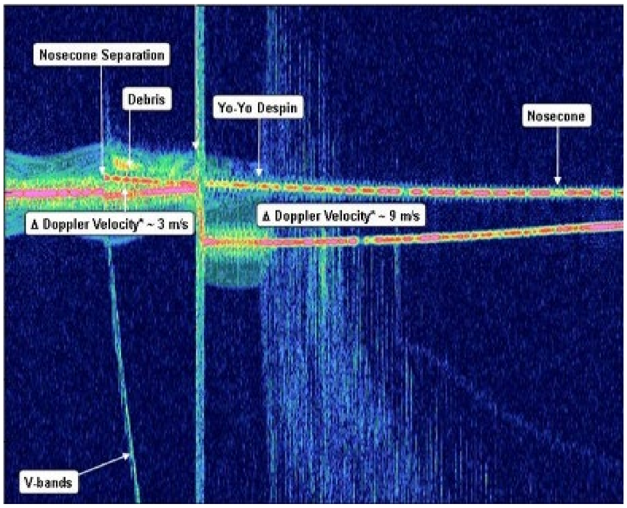
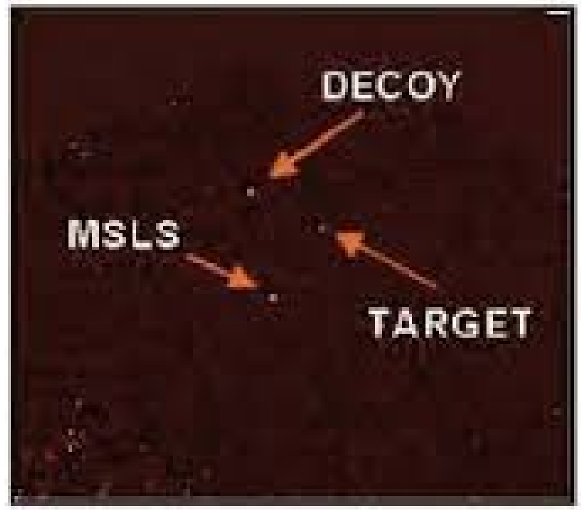
Instrumentation	Tactical
	
Accurately measures known airborne objects from vast list of possible object types. Focus is on highly accurate data on known targets.	Discrimination to identify lethal object and reject decoys or debris in real time to support weapon direction.
Acquires raw in-phase and quadrature (I&Q) measurements of noninstrumented inflight phenomenology for postprocessing. Accuracy specified as angle, range, and velocity accuracy.	Detect and characterize threats, often from limited and known threat types.
Radar must be significantly more accurate than SUT.	Focus is on detection and track information on multiple unknown targets. Probability-of-detection and probability-of-location, accuracy may be specified as impact prediction accuracy.

Table 8. Deploy and Operate in Hostile Area with Opposition	
Instrumentation	**Tactical**
	
Not Required. Deployed at MRTFB ranges. May be taken on remote operations to tropics or arctic conditions.	Primary environment is hostile locations world-wide with environmental extremes. Requires ruggedization.

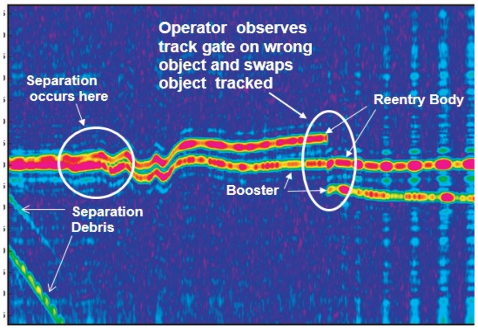
Table 9. Situational Awareness	
Instrumentation	**Tactical**
	
Provides focused awareness within the planned scenario.	Provides awareness over broad area with no advanced knowledge.
Provides stream of accurate TSPI data for range safety and to cue other instrumentation systems.	Provides real-time alarms, flight path, probable impact location, firing solution.
Accurate TSPI and pointing/cueing information in real-time, quick-look data products to assess flight success within a few minutes, postflight analysis of multichannel I&Q data to determine detailed flight dynamics, proper deployments, and cause of SUT failures.	

Table 10. Countermeasure Resistance	
Instrumentation	**Tactical**
	
Provides electromagnetic interference resistance.	Requires resilience to electromagnetic pulse and chemical/biological attack.
Typically operates in a band different from SUT.	Extensive resistance to electronic attack.

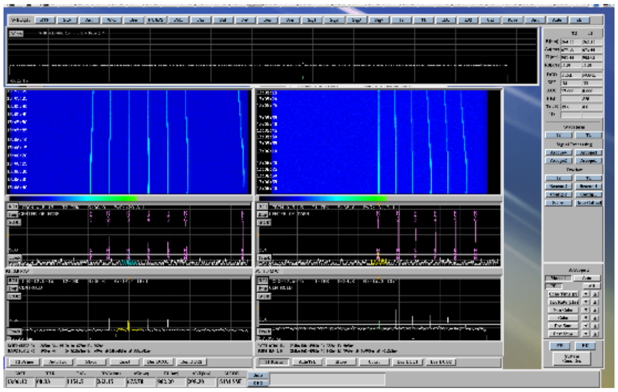
Table 11. Users	
Instrumentation	**Tactical**
	
Operators and engineers trained in radar theory, functionality, and how to capture data to evaluate SUTs. Typically have years of experience with system.	Operated by Soldiers.
Mission oriented protective posture gear not required.	May wear mission oriented protective posture gear.
Extensive operator configuration and adjustment are available.	Automation is generally desirable.
Automation is generally undesirable due to it tendency to limit the systems adaptability for multiple types of targets/missions and ability for operator to take over when missions don't go as planned.	Limited operator adjustment due to the focus on ease of use.

Table 12. Transponder	
Instrumentation	**Tactical**
Complete flexible transponder track. Codes and other parameters are operator selectable.	Transponder track of own weapon. Typically not changeable in the field.

Table 13. Classification

Instrumentation	Tactical
Hardware and software must not be classified to allow flexibility in maintenance and calibration procedures, must collect classified or unclassified data, and must be able to readily switch between classified and unclassified environments.	 Hardware and software must not be classified to allow flexibility in maintenance and calibration procedures, must collect classified or unclassified data, and must be able to readily switch between classified and unclassified environments.

6. Conclusion

The goal for this document was to define an instrumentation radar, answer questions the DoD MRTFB ranges have received when discussing instrumentation radar projects, and provide some examples of why instrumentation radars are different than other radar categories. A lot of effort was expended specifically on comparing instrumentation radars to tactical radars. The intent was to say a tactical radar can be an instrumentation radar, but it may require a significant re-engineering and replacement of components and the addition of extensive I&Q data recording capability to fit the specialized nature of instrumentation radars.

This page intentionally left blank.