Combining Air Defense and Missile Defense

Brigadier General Armament Corp (ret.) Michel Billard
Thalesraytheonsystems
1 Avenue Carnot
91883 MASSY CEDEX
FRANCE

michel.billard@thalesraytheon-fr.com

ABSTRACT

A number of NATO Nations will use fixed (or deployable) Long Range Air Defense Radar fitted with ATBM capabilities.

France is developing a new generation of Deployable Multi Mission Radar (M3R), which will be associated with the SAMP-T SAM system and C2BMC components in an architecture ensuring both Air Defense (against Air Breathing Targets) and TBM Defense for Deployed Troops.

This paper focuses on some of the main challenges which the dual purpose architectures built around these Radar will have to face and provides relevant design drivers.

Some of the main issues addressed will be:

- *How to optimize these multi purpose Radar siting*
- *Where and how should the Radar be controlled to handle their two missions (AD & TBMD)?*
- *How to combine direct sensor to shooter link with complex multi element architectures, in an open (inter operable) architecture?*

1 PURPOSE

Theatre Ballistic Missile Defense Systems are likely to use multi purpose Long Range Air Defense Radar for Early Warning and Tracking of Ballistic Targets.

These multi purpose radar may be of two kinds:

- **The ATBM capable LRAD Radar**: this is a "Classical" Long Range Air Defense Radar, mostly fixed and sometimes deployable, with rotating antenna and data renewal rate around 10 seconds, configured and sited for general Air Surveillance but fitted with ATBM processing enabling it to detect and track TBM objects within its coverage (e.g. radar following NATO FADR MOR, TRS MASTER M, TRS 22XX,...).
- **The Mobile Multi Mission Radar (MMR)**: this is a mobile (deployable) Radar with azimuth / elevation electronic scanning and multiple working modes ("classical" rotating antenna Air Surveillance modes, ATBM staring or rotating antenna modes, mixed modes,...). These Radar are likely to be part of Deployed Forces configuration for Overseas Operations (e.g. TRS MASTER A, TRS M3R).

Billard, M. (2005) Combining Air Defense and Missile Defense. In *Design Considerations and Technologies for Air Defence Systems* (pp. 6-1 – 6-8). Meeting Proceedings RTO-MP-SCI-143, Paper 6. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

Using these multi purpose Radar in Architectures which combine Air Defense with Missile Defense will result in architecture design constraints specific to the kind of Radar involved. The purpose of this paper is to analyse these constraints and provide some relevant associated key architecture design drivers.

2 ARCHITECTURES INVOLVING ATBM CAPABLE LRAD RADAR

2.1 ATBM Capable LRAD Radar Concept of Operations

The basic concept here is to use some of the LRAD radar involved in Homeland Airspace Surveillance (those nearest to the Threat and / or fitted with ATBM processing) for ATBM Early Warning and Tracking.

It will not impact the overall requirements for data renewal rate (antenna rotation speed) or surveillance elevation coverage.

It may however impact slightly the requirement for tracking elevation coverage (30° desirable, instead of 20°) and for altitude coverage (>100000 ft. desirable).

The ATBM function will not impact significantly AD performances (marginal impact possible in case of heavy TBM track load).

But this ATBM function does impact System Architecture and associated BMC3 functions.

2.2 Associated Architecture Design Drivers

The key design driver here is the necessity to detect a TBM object as early as possible and before it goes above the LRAD Radar (search) elevation / altitude coverage.

In order to achieve this early detection, it is highly recommended to site LRAD Radar in such a way that their coverage overlap (for two or three of them) over the most likely launching areas.

Once this is done, the TBM detection / confirmation strategy should be as follow:

- In the low elevation zone (and for relevant azimuth zone) all “covering” LRAD Radar send all their surveillance detections (plots) with attributes (amplitude, Doppler,…) to a centralized BMC3 extraction function. It is understood that, within these potential launching zones, the LRAD Radar detection threshold should be lowered (with respect to normal stand alone AD surveillance detection threshold).
- The BMC3 establishes TBM presumptions and sends confirmation measurement requests to relevant radar.
- The relevant radar confirm and track the TBM object and the BMC3 establishes track fusion (RPC task), LPE / IPP (with the help of its central Intelligence Data Base) and distributes the related tactical information (recognized TBM picture).
- For time delays optimisation (and robustness), each tracking radar also establishes a “local” track complete with LPE / IPP (using its local Intelligence Data Base), which is normally superseded by the BMC3 information as soon as it exists.
- The BMC3 then updates its central Intelligence Data Base and the local ones.
- Communications between the LRAD and BMC3 uses specific high data rate links.

Note that, as a consequence, the related BMC3 function should be implemented near the “central” Intelligence Data Base.

3 ARCHITECTURES INVOLVING DEPLOYABLE MULTI MISSION RADAR

3.1 MMR Concepts of Operation

Two possible Concepts of Operations are briefly sketched below.

The first one relates to Deployed Forces Operations and is the French Concept for the M3R program associated with the French “capability 1” ATBM Architecture.

The baseline is omni directional and multi threat protection of limited areas with one single sensor. It covers Classical Air threat, Cruise Missiles and Short Range TBM’s (<600 km).

The MMR is in charge of cueing to the associated Weapon System(s) (e.g. SAMP-T). Protection of the MMR is done through the Weapon System.

The MMR is remotely operated through a DARS type C2 Center.

The second one relates to Forward Area Operation in relation with an ABM Boost Phase Kinetic Energy Interceptor (KEI).

Here, the MMR is in charge of confirmation of Space sensors Early Warning and accurate designation to the KEI. Radar Siting is near the KEI, that is a few hundred kms from hostile LRBM launching sites.

The MMR also provides 360° Air Surveillance for self and KEI protection against A/C & Missiles attacks.

In all cases Multiple Modes (AD and BMD, Staring and Rotating) Management is required.

3.2 MMR Radar Siting

Due to its multiple missions, the MMR Radar siting will have to take into account a larger set of constraints which will have to be weighted in order to optimise the favoured performances.

The set will depend upon the Concept of Operation.

For Deployed Forces Operations, the main constraints will be (normally in priority order)

- Constraint 1: optimize Low Altitude coverage
- Constraint 2: optimize foot print of associated W.S.
- Constraint 3: optimize M3R self protection
- Constraint 4: facilitate Communications

In Forward Area Operations associated with KEI, the main constraints will be (also in priority order):

- Constraint 1: optimize Launch Area visibility (min. dist.)
- Constraint 2: optimize local Low Altitude coverage
- Constraint 3: facilitate Communications

In both cases tools exist, like TRS “MUSE” tool, and should be employed to facilitate the siting optimisation process at strategic level (planning). The figure below illustrates coverage maps obtained with MUSE.

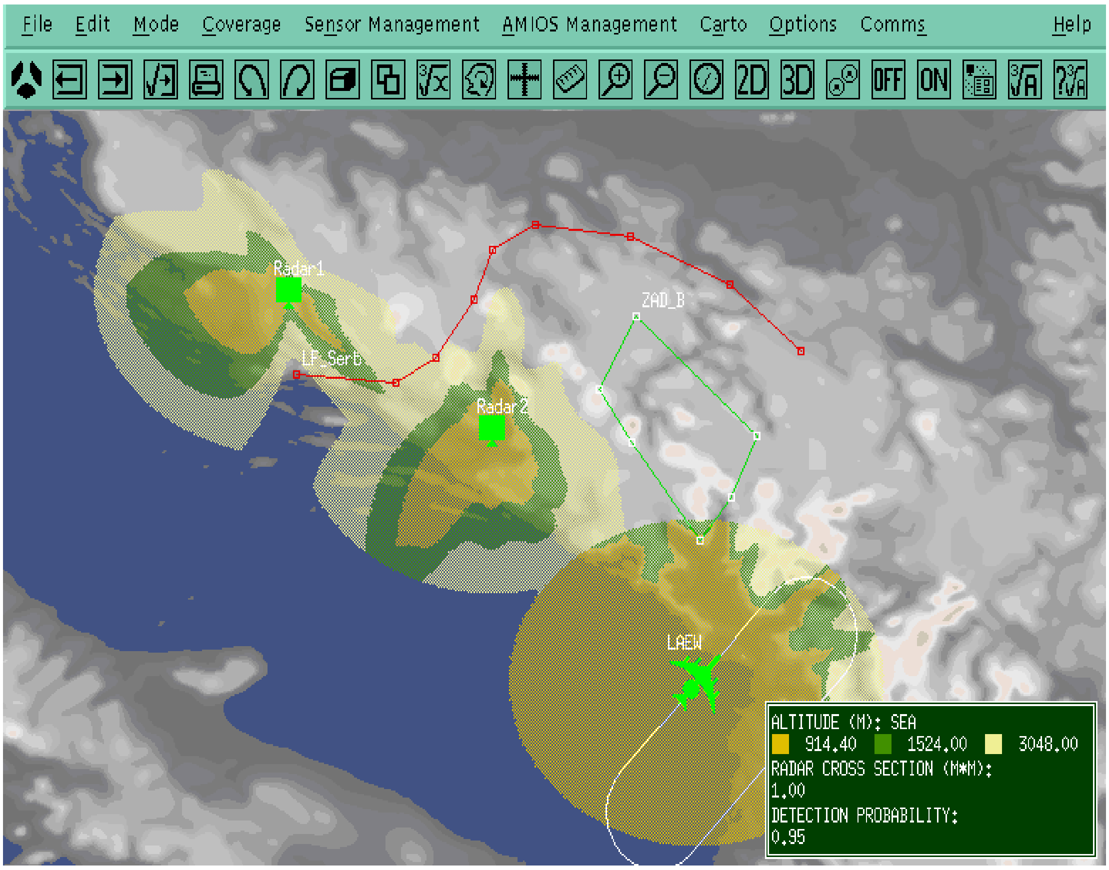
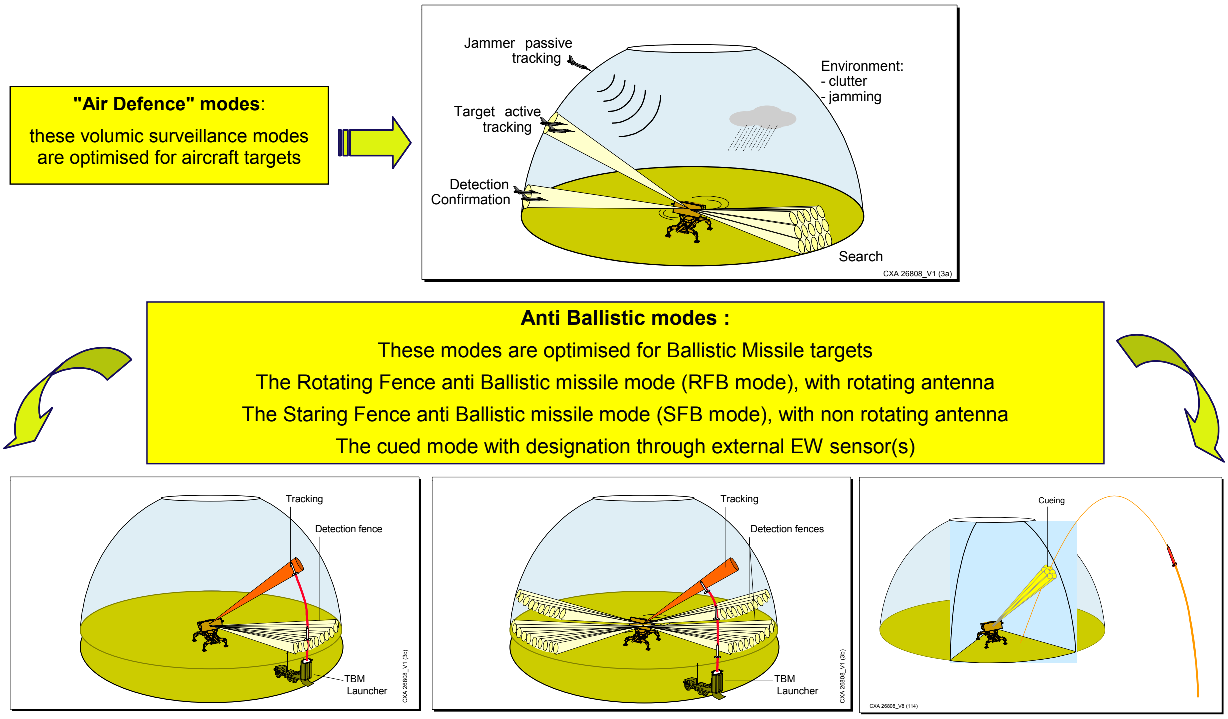


Figure 1: Radar Coverage Obtained from "MUSE" Tool.

3.3 MMR Radar Mode Management

The MMR Radar will use a number of different modes for Classical Air Defense or for ATBM Defense. It may use them sequentially (in successive azimuth zones), concurrently (in the same zones) or separately, depending on the operational situation. These modes may use a rotating or a staring antenna.

Some of these modes are illustrated below.



Staring antenna ATBM fence mode **Rotating antenna ATBM fence mode** **Cued mode**

Figure 2: Some MMR Radar Modes.

This diversity in MMR Radar modes will have two major impacts on the related BMC3:

- The mode management will have to be shared between the MMR itself and the BMC3
- The mode management will have to take into account trade off in Radar time utilization, according to Operation priorities.

Trade Off

The following example illustrates the kind of trade off which will have to be taken into account. It relates to a **purely fictive generic radar** and has been generated by using the radar equation only. All similarity with existing radar would then be a pure coincidence but the main point is that the order of magnitudes and the relative figures are a mere consequence of Physics and therefore unchallenged.

Suppose a generic MMR radar designed for detection of 1 m^2 targets at 400 km with Pd = .9 in a rotating antenna Air Surveillance mode with 10 seconds rotation period, elevation domain 0 to 20°, beam positions sampling at 1° in azimuth and elevation and 20% radar time devoted to non surveillance functions.

This generic radar, in rotating antenna mode, will be able to:

- Detect TBM of .1 m^2 at 480 km with Pd = .9 in a 1 beam width elevation fence surveillance mode (exclusive)
- Combine both above modes in same az. zones with a range loss of ~20%
- Alternate above modes according to azimuth zone with no range loss
- Track a maximum of, say, 400 A/C (1 m^2) at maximum range without surveillance degradation

- Track a maximum of 20 TBM (.1 m2) at maximum range (exclusive) without surveillance degradation
- Mix A/C and TBM tracks with 1 TBM track = 20 A/C tracks

And in staring antenna mode:

- Detect TBM in fence mode (1 elev. Beam width) on 90° azimuth Sector at 600 km with 7.5 sec. Scan time
- Track a maximum of 8 TBM at maximum range of 600 km without surveillance degradation
- Acquire on cueing (1 beam width x 1 beam width accuracy) and track one TBM at maximum range of 1000 km without surveillance degradation
- Acquire on cueing (1 x 1) and track 2 TBM at 1000 km with 20% degradation of surveillance function

As can be seen, range costs a lot time wise (4^{th} power involved), then cueing (for cued mode) has better be accurate. But "sharing time (in the same zone) between two modes "costs" only about 20% decrease in range performances.

Modes (Radar Measurements) Management: Who is in Charge?

This management will have to be shared between the Radar itself and the BMC3 (DARS for Deployed Forces Operations).

The optimisation of related task allocation will have to take into account the following features:

The MMR Radar:

- Has first hand knowledge of its internal state and of environment
- Can use Intelligent Radar Management techniques
- Is able to reconfigure itself in real time
- May use its local Intelligence Data Base

The BMC3 (DARS):

- Has knowledge of global Threat Assessment
- Has access to external sensors data
- Has access to up to date intelligence information
- Is responsible for C2 resources management
- Has "man in the loop"

Starting from there, an optimised task allocation will have to be implemented for the different functions included in Radar management. A list of these functions is provided here:

- Cueing
- Surveillance zone management
- TBM alerting and LPE / IPP
- Classification of TBM / Space tracks

- Target Object Map establishment
- Anti ARM and ECCM Management
- High resolution measurements Management

As an illustration, tables of task allocation are provided below for the two first functions.

Cueing

	MMR	DARS
Choice of ext. tracks to acquire by MMR		★
Number of measurements (volume to explore)		★
Maximum measurement time		★
Management of measurements within radar time	★	

Figure 3: Cueing Task Allocation.

Surveillance Zones Management

	MMR	DARS
Definition of surv. Zones and related scan times		★
Priorities allocation		★
Surv. & tracking interdiction zones definition		★
Management of measurements within radar time	★	
elaboration of load per sector information	★	

Figure 4: Surveillance Zones Management Task Allocation.

3.4 The Sensor to Shooter Link

The challenge here is to keep a direct line of communication (with minimum and predictable latency) between the Early Warning Radar sensor and the weapon system(s) while accommodating different configurations for the system (sensors + Weapons + BMC3). This will allow optimisation of the Weapon reaction time, which is essential for Lower Layer TBM interception, while keeping the possibility to authorize (or forbid) engagement at BMC3 level.

Different possible architecture solutions are sketched below and it can be seen that the most flexible solution, therefore the preferred solutions, uses a Tactical Data Local Area Network (Link 16) with the MMR Radar itself configured as a “Joint Unit” L16 subscriber.

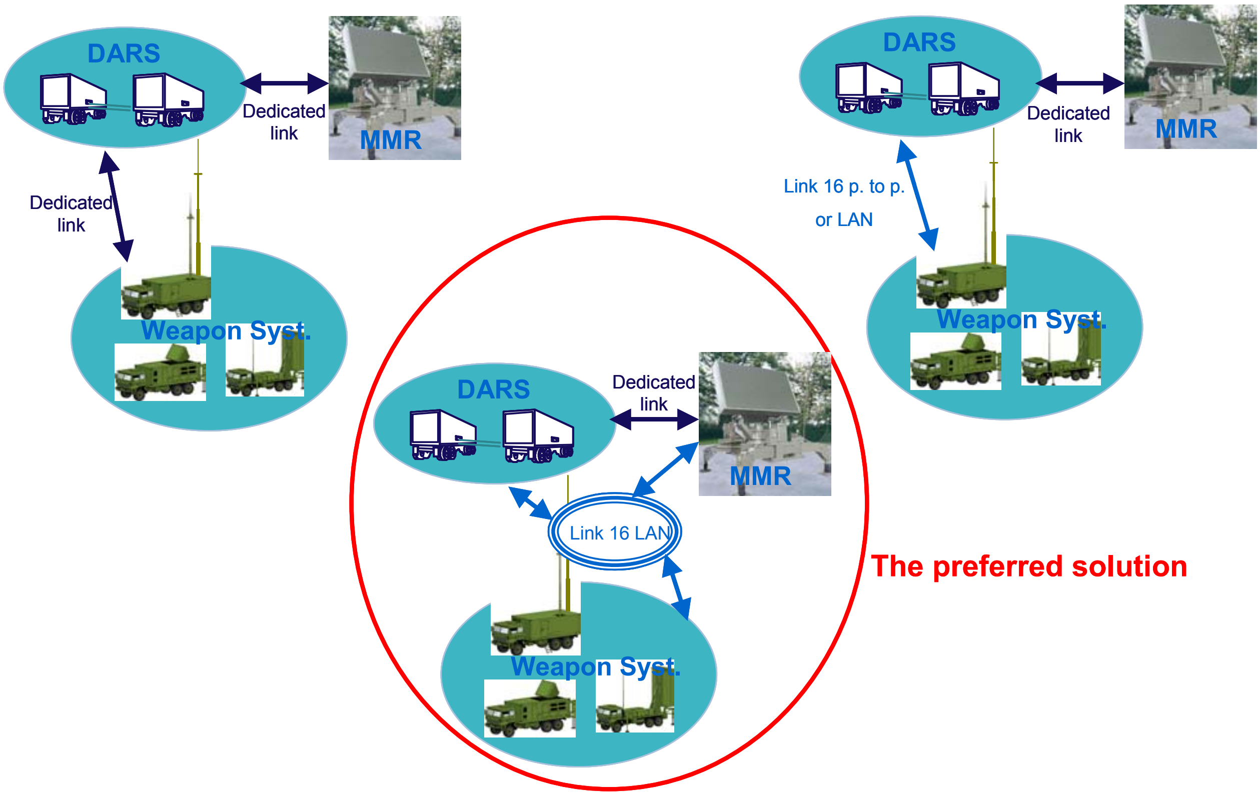


Figure 5: Sensor to Shooter Link, Possible Architectures.

It should be noted, furthermore, that this preferred solution will allow direct and easy link (for tactical data) with other Friends and Allies Systems, thus ensuring interoperability. It is an open and Network Centric Architecture.

4 CONCLUSION / SUMMARY

Future Theater Ballistic Missile Defense Systems are likely to use Ground Based Multi Purpose Long Range Radar also involved in « classical » Air Defense.

Hence the necessity of combining Air Defense and Missile Defense Architecture in a way which will optimize performances for both architectures.

If the multi purpose radar are fixed rotating antenna LRAD radar with ATBM capabilities (e.g. NATO MOR), the main ATBM architecture design driver will be to combine raw output from several radar (at BMC3 level) in order to get early acquisition and continuous tracking on TBM in spite of radar elevation coverage limitations.

If the multi purpose radar are deployable (rotating or staring antenna) multi mission radar the main ATBM architecture design drivers will be to:

1) optimize radar siting,
2) manage radar modes at BMC3 level,
3) optimize sensor to shooter data link.