Report of the Defense Science Board Task Force

on

Aerial Targets

October 2005

Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

THE UNDER SECRETARY OF DEFENSE

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ACQUISITION,
TECHNOLOGY
AND LOGISTICS

13 Sept 2005

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION, TECHNOLOGY, & LOGISTICS)

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Aerial Targets

I am pleased to forward the final report of the DSB Task Force on Aerial Targets. This effort, chaired by Mr. William Delaney and General Michael Williams (USMC-Ret) assessed the future needs for aerial targets in testing our land and sea-based air defense systems. The Task Force found several areas for concern.

- The use of drone versions of the F-4 aircraft as our single full-sized airplane target will end in the foreseeable future as we run out of usable platforms. A replacement vehicle is needed and the Task Force recommended approaches for the mid-term and the long term.
- Our most serious gap in aerial targets is in the area of supersonic anti-ship cruise missiles. A number of such missiles have been deployed by several countries, but we have not yet achieved a stable capability to conduct critically-needed testing against these challenging targets. The Task Force made recommendations for the aggressive acquisition of three specific types of supersonic test targets.

The Task Force recommended that the newly-formed Department of Defense Test Resource Management Center (DTRMC) provide a more centralized planning and coordination process for aerial test targets. An initial task here would be to begin the migration of service test assets to a common form with the ultimate goal of being able to test any target on any range.

I endorse the Task Force's recommendations and encourage you to review the report.

William Schneider, Jr.
DSB Chairman

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September 2005

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board Task Force on Aerial Targets

Attached is the final report of the Task Force on Aerial Targets. The Task Force assessed the needs for aerial targets in the 2005-2020 era for testing of a wide variety of air defense systems. The spectrum of aerial targets involves full-sized aircraft, subsonic and supersonic cruise missiles, rotary-wing vehicles and UAVs. Ground systems and on-board instruments for target control are also involved.

Aerial target testing is about a $220 million per year enterprise which involves some 750 flights per year using ten different targets. About 200 of these flights result in destruction of the target so development and procurement of new targets is a major activity.

The Task Force found four areas of concern in their review:

- The need for a new full-scale aircraft target
- The dire need for several types of supersonic targets to represent existing anti-ship cruise missile threats
- The need for migration to a future common control system across the services so that all services could test on all major ranges.
- The need for a more centralized and focused aerial targets management structure in OSD

We are projected to run out of the inventory of our single full-scale target, the QF-4, a drone version of the F-4 aircraft, about 2011. A decision on a replacement aircraft is needed soon to avoid a gap in full-scale target availability. The Task Force recommends the development of a drone version of the F-16 aircraft because it can provide a substantial supply of surplus aircraft for many years to come. A competing view is to try to continue with F-4 aircraft even though the F-4 variants now available will be increasingly costly to modify into drone vehicles.

The Task Force recommends our future full-scale target effort should strive to eliminate the need for a man-rated aircraft because it is a major driver of vehicle cost. The F-16 option would allow removal of the wings for ground transportation.

The F-16 option should be considered an interim solution, intended to avoid a gap in full scale target availability. The F-16 may not be representative of a fifth generation fighter threat.

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Accordingly, the Task Force also recommends a concept development effort for a full-scale target to emulate advanced aircraft threats exploiting low-observable technologies.

The area of greatest concern to the Task Force was our gap in supersonic anti-ship cruise missiles for testing. The Russians have deployed at least three such cruise missiles that involve either sea-skimming flight profiles or a high-altitude profile involving a power dive to the target. At this time, we have no test vehicles for either flight profile. The Task Force supports the current Navy acquisition process for one type of sea-skimming missile and recommends additional aggressive efforts on another sea-skimmer with a unique flight profile and a high-altitude vehicle with a power-dive attack profile.

The systems which control our aerial vehicles tend to be Army, Navy and Air Force specific, thus, one service would find it difficult to test on another service's range. This situation will increase the difficulty of conducting joint testing and training. The Task Force can envision the gradual introduction of common control elements into each range to provide an increasing degree of interoperability, test flexibility, and lowered operational costs. The Task Force recommends the recently formed DoD Test Resource Management Center (DTRMC) take on this initiative.

The Task Force also saw the need for a more centralized and focused OSD oversight of aerial targets and testing and recommends that the DTRMC take on this responsibility.

The Task Force Membership stands ready to assist the various DoD components in the interpretation and implementation of our findings and recommendations.

William P. Delaney
GEN Michael Williams, USMC (Ret.)

Task Force Co-Chairmen

Table of Contents

Executive Summary	1
Introduction	5
Organization of this Report	5
Overview of Aerial Targets	6
Pressing Aerial Target Needs	8
Recommendations on Full-Scale Targets	11
Supersonic Cruise Missiles	12
Recommendations – Supersonic Cruise Missiles	16
Target Control Systems	17
Recommendation on Target Control Systems	18
Related Questions	18
Helicopter and UAV Aerial Targets	21
Management Planning and Oversight	21
Recommendation	21
Recommendation Summary	22
Appendix A: Terms of Reference	A-1
Appendix B: Task Force Members	B-1
Appendix C: Briefings Received	C-1
Appendix D: Compendium of Aerial Targets	D-1
Appendix E: List of Acronyms	E-1

Executive Summary

The Defense Science Board Task Force on Aerial Targets was convened in December 2004 to assess the future (2005 to 2020) needs for aerial targets for developmental and operational testing and for training of air defense systems against air-breathing threats. Ballistic missile threats and targets were not part of the Task Force charter. The aerial targets involve full-scale aircraft, subsonic and supersonic cruise missiles, rotary wing vehicles, and unmanned aerial vehicles (UAVs). Ground systems and on-board instruments that control the targets are also relevant.

Testing and training against aerial targets involves roughly 750 flights per year using 10 different targets. About 200 of these flights result in the destruction of the target, so a substantial development and procurement program is in place, involving about $220 million funding per year.

The Task Force found four areas of concern in its review of the future needs for targets and control systems out to the year 2020:

- The need for a new full-scale aircraft target.
- The dire need for several types of supersonic targets to represent existing anti-ship cruise missile threats.
- The need for migration to a future common control system across the services, so that all services could test on all major ranges.
- The need for a more centralized and focused aerial targets management structure in OSD.

Full-Scale Targets

The current full-scale target is a drone version of the F-4 fighter aircraft called the QF-4. The available inventory of QF-4 targets will be depleted by about 2011 at the current usage rate of 25 per year and the current production rate of about 20 per year. A decision on a replacement aircraft and a plan to develop the necessary hardware to make it a drone is needed soon. The Task Force believes the development of a drone version of the F-16 aircraft, a QF-16, could fill this need and provide suitable mid- to long-term availability. This approach involves up-front development costs, which are causing resistance in the services. A competing approach is to continue to modify available F-4 aircraft, even though the modification costs will continue to grow as the most suitable F-4 variants are used up.

One issue deserving careful assessment is the need for man-rating of the full-scale target. A non-man-rated air vehicle would cost 30 or 40 percent less. A QF-16 approach facilitates this non-man-rating since the wings on an F-16 can be removed for ground transport.

An additional concern was the likely future appearance of an advanced foreign-made fighter with stealth features. A QF-16 would not likely be able to capture the radically different radar and optical signatures of such an advanced aircraft. The Task Force recommended a concept development effort to deal with this future possibility.

Supersonic Cruise Missile Targets

The Russians have produced and deployed a variety of supersonic, anti-ship cruise missiles. Some of these missiles are sea-skimming vehicles; others attack from high altitudes. At the time of the Task Force, the United States had zero capability to test its air defense systems such as AEGIS or Improved Sea Sparrow against supersonic targets, and the Task Force views this shortfall as the major deficiency in our overall aerial targets enterprise. Aggressive actions are needed to fix the problem.

The Task Force had recommendations on three supersonic target development activities:

> **GQM-163A**: This is a U.S.–built, supersonic, sea-skimming vehicle that is currently entering initial production. The development program had a number of failures, and there is remaining risk in the production effort. However, the Task Force agrees with the Navy's decision to push ahead with production because of the dire need for this class of target.
>
> **MA-31**: The MA-31 is a Russian-built, supersonic, high-altitude, anti-ship cruise missile target that uses a powered dive in the terminal phase of its attack on a ship. The U.S. had been able to buy 18 of these missiles in the past, but our current effort to buy 40 more is stalled by bureaucratic delays in Russia – likely occasioned by the varying political climate between the U.S. and Russia. No backup plan to develop or procure a suitable substitute target was evident to the Task Force. The Task Force supports continued efforts to buy MA-31s, but recommends the immediate formulation of a backup plan.
>
> **Threat D**: Threat D is a Russian sea-skimming, anti-ship cruise missile with a unique flight profile. It starts with subsonic flight, but as it nears its ship target, the vehicle separates into two sections, and the warhead stage flies a supersonic, sea-skimming profile to the target. This subsonic-supersonic transition and the separation of the vehicle into two pieces may present a source of confusion to a ship's defense system. A test target that emulates this unique target profile is needed.
>
> The Applied Physics Laboratory of Johns Hopkins University conducted a study of ways to emulate a Threat D profile. They found that a Tomahawk cruise missile with a Standard Missile-2 (or an Improved Hawk) front end could produce a viable subsonic-supersonic profile.

The Task Force recommended that the Navy quickly procure some Threat D-type test targets. A "skunk works" approach using existing components such as identified in the Applied Physics Laboratory study seemed an effective approach to the Task Force.

Target Control Systems

The Army, the Navy, and the Air Force at Ft. Bliss, Point Mugu, and Tyndall AFB, respectively, have each developed their own one-of-a-kind target control system, both the ground-based instrumentation and the target control electronics that flies on the various air vehicles. Interoperability is limited, and the flexibility to use each other's test range resources is absent. One can envision the gradual introduction of common control elements that would eventually provide us with the ability to "shoot any target on any range." This approach will yield operations cost savings over time, since today's one-of-a-kind systems will become increasingly difficult to service, maintain, and upgrade. Target interoperability will also facilitate better joint testing and training.

Past attempts at common control have failed. The Task Force believes another attempt is worthwhile if service "buy-in" can be achieved. The Task Force recommends that the newly-formed DoD Test Resource Management Center, DTRMC, lead this migration to a common control system.

Management Planning and Oversight

The Task Force saw the gap in supersonic test targets and the approaching gap in full-scale targets as evidence of the need for a more centralized and focused OSD oversight of aerial targets. The DTRMC seems to have this charter, as well as an avenue to influence the resources applied in this area, but it is not absolutely clear. The Task Force recommends that the USD(AT&L) clarify the role of DTRMC so that its charter unambiguously includes aerial targets and their control systems, and direct DTRMC to take on the long-range planning for aerial targets and target control systems.

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Introduction

The Defense Science Board Task Force on Test and Training Sub-scale and Full-scale Aerial Targets was convened in December 2004 and concluded its deliberations in July 2005. The Task Force was chartered to assess the future need for full-scale and sub-scale aerial targets for developmental and operational testing and for training of our air defense systems operators. Ballistic missile targets were not part of the charter. The full Terms of Reference for the Task Force are in Appendix A. The three principal elements of the Terms of Reference were an assessment of:

- Future aerial target needs (2005-2020) for developmental and operational testing and training.
- Alternatives to replicating supersonic sea-skimming threats such as "Threat D."
- Test range instrumentation needs of the future.

In addition, the Terms of Reference contained four testing-related questions:

- To what extent can modeling and simulation supplement live target testing?
- Can a common aerial target configuration serve a variety of programs?
- Does a target need to replicate the total threat flight profile or only parts of it?
- What is the degree of fidelity required in threat representation?

Organization of this Report

The remainder of this report is organized into the following sections:

- Overview of Aerial Targets
- Pressing Aerial Target Needs
- Range Instrumentation, Target Control Needs
- Related Questions
- Management Planning and Oversight
- Recommendations Summary
- Appendices

The Task Force Membership is in Appendix B, and a list of briefings to the Task Force is in Appendix C. Appendix D provides summary information on each of the aerial targets discussed in this report and Appendix E is a glossary of abbreviations.

Overview of Aerial Targets

Table 1 provides a quantitative view of aerial target testing and training. Most aerial targets are recoverable and usable for multiple flights but supersonic cruise missiles are generally not recoverable. It is a substantial enterprise involving some $220 million in yearly funding. Table 2 shows how this aerial target funding is divided across the Services and OSD.

Table 1. Aerial Target Testing

750 flights per year – involving ten different targets
197 of the targets flown were expended in a recent year (151 shot down, 46 crashed)
About 140 targets produced per year in four production programs
870 targets in the current inventory (mostly BQM-34, BQM-74, AQM-37)
$220 M aerial target funding in FY05 (RDT&E, procurement)

Table 2. Aerial Target Budgets (RDT&E and Procurement)

Service	FY-05
Navy	110 M
Air Force	82 M
Army	13 M
DOT&E	15 M
Total	$ 220 M ±/Year

The aerial target program involves a wide variety of vehicles and related instrumentation, as shown in Figure 1. The Task Force focused its major efforts on the

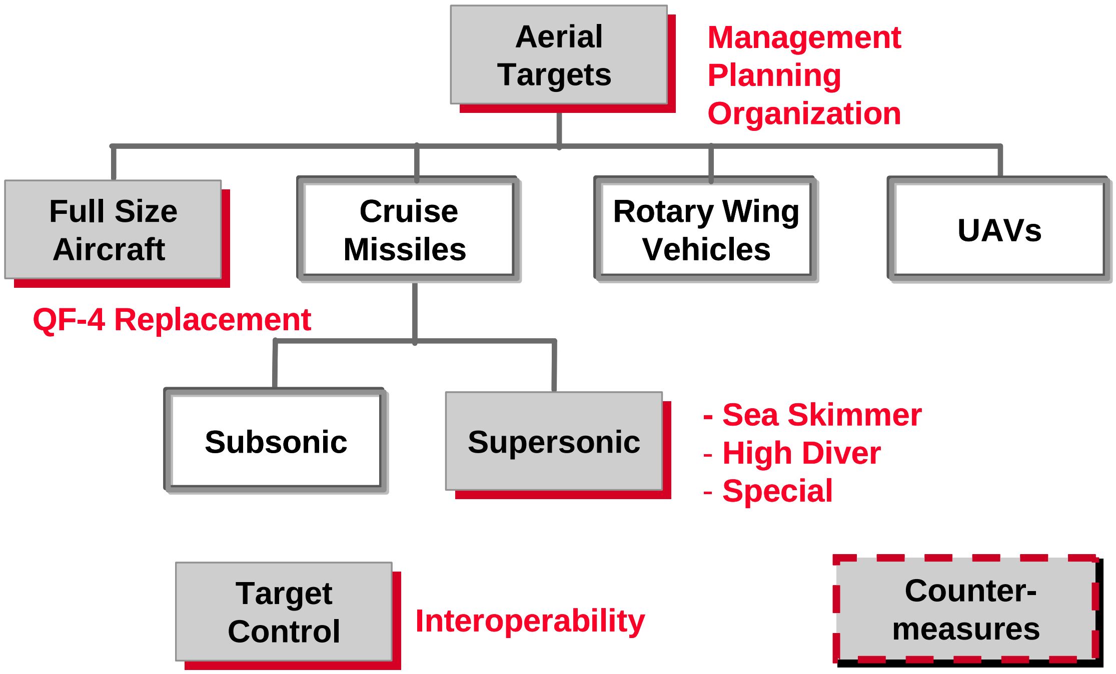


Figure 1. Task Force Focus

five areas shown as shaded in the figure where, in the Task Force's view, there were major concerns and shortfalls. Our highest concern was the lack of an adequate set of target vehicles to represent a variety of deployed supersonic anti-ship cruise missiles. Our next concern was the inadequate near-term supply of full-size drone aircraft for testing. Both of these shortfalls point to deficiencies in the management and future planning for air vehicle testing, which was our third concern.

There are likely to be major gains in efficiency and flexibility in testing and training if we can migrate to a more common set of target instrumentation and range instrumentation. This was our fourth concern.

Our fifth concern, the issue of countermeasures, needs special mention here. While there is much tension and concern in the testing community with the accuracy of threat replications, there is seemingly much less angst over enemy on-board countermeasures. Yet, these countermeasures can dominate the outcome of an engagement of an enemy air vehicle. The nature of specific electronic countermeasures that might be carried on, say, a Russian-built anti-ship missile are very hard to deduce, whereas the general size, shape, and kinematics of such a cruise missile are more easily obtained through classical intelligence gathering. This presents a substantial challenge to the air defense test and training community. It needs to deal with this issue by testing our weapon systems against a wide variety of countermeasure techniques. This general lack of detailed threat countermeasure information should also temper the test community's frequent concern with the exact replication of threats. We will say more about this in the section on "Related Questions."

The predominant number of aerial targets are subsonic drones that are used for a variety of test and training purposes. We found no major issues with these targets. Appendix D provides summary information on these targets, which are not discussed further. We do include short commentaries on rotary wing and UAV test vehicles.

Pressing Aerial Target Needs

Figure 2 shows the principal aerial targets in use today. The targets in the boxes received our major attention. We will discuss the full-scale target situation first.

Full-Scale Targets

Figure 3 outlines the current full-scale target situation, which relies exclusively on a drone version of the F-4 fighter aircraft called the QF-4. Full-scale targets are a necessary part of our test target inventory, because certain aspects of an engagement by a missile depend on geometric and signature details that can be captured only by a large airframe. One example of this is related to the final guiding and fuzing of a radar-guided missile where glints from overlapping returns from different areas of an extended target will affect the performance of the missile differently from that associated with a small, compact target. In general, miss distance will increase towards the end of the engagement, particularly for today's high performance missiles that employ fast response times. Another example is the lethality of the missile: how effective is the blast pressure, the warhead fragments (along their relative velocity vectors to various locations along the extended target) and the missile body contact, if achieved, in bringing down the target. While static tests against replica vehicles can play a partial role in examining the combination of missile warhead effectiveness and target vulnerability, it is not until all elements of the missile are brought together – warhead, fuze, closing velocity and end-game geometry – and tested against full size targets that we gain the necessary confidence. This is particularly true today as we go to smaller and smaller warheads and depend increasingly on direct hits or lethality enhancers

That said, we do not have a drone version of a large bomber or transport-sized aircraft; the cost here is probably just too high. Certainly, our first priority is a fighter-size aircraft.

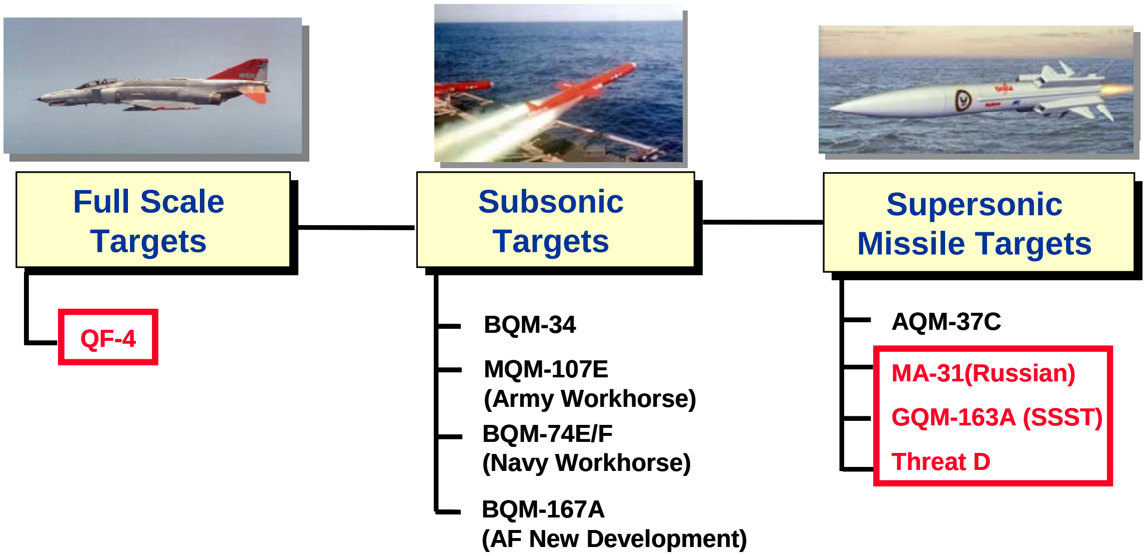


Figure 2. Principal Aerial Targets

<u>Status</u>: Only full-scale target – inventory will be depleted about 2011

<u>Unit Cost</u>: $2300 K

<u>Current Inventory</u>: 53

<u>Current Expenditure Rate</u>: 25 per year (across all three services)

<u>Production Status</u>: About 150 QF- 4s produced in past – current production program: 20 per year

Figure 3. Full-Scale Aircraft Targets QF-4 Drone

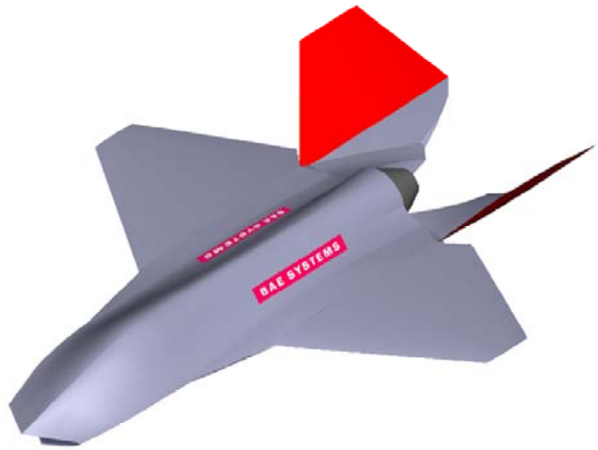
The problem is that our inventory of suitable F-4 aircraft will be exhausted about the year 2011. A replacement airframe must be selected soon, and the design of the drone modifications needs to begin immediately. The Task Force sees three issues here:

1. What will be the replacement airframe for the QF-4?
2. Does this new drone have to be man-rated? (A cost issue.)
3. How do we capture in testing the advanced threat aircraft of the future (e.g., stealthy aircraft)?

The F-16 is the most suitable candidate airframe for replacing the F-4. A drone version of the F-16 would involve upfront development costs. A competing approach to avoid these costs is to modify foreign F-4s. Apparently there are many F-4 variants in existence around the world but these variants would generally be more expensive to modify. The "good" F-4s are quickly being used up. So the decision seems to rest on upfront spending versus longer term expenditures for more expensive drone aircraft. The Task Force believes this decision can and should be made quickly to avoid a gap in target availability.

A key consideration in this decision is the need to have the drone man-rated. This is an important cost issue, with the man-rating capability costing roughly one-third of the $2 million cost of the drone. There may be substantial arguments for the man-rating, but the Task Force did not hear them. Man-rating makes it easy to ferry the drone aircraft to the range where it is to be used, but our impression is that there are few such ranges and the aircraft could readily be ground-transported there. Ground transportability would require removable wings. The F-16 has removable wings, the F-4 does not. Any analysis of full-scale target choices must consider the man-rating issue as an important cost element.

A second concern with the plan for replacing the existing full-scale target is the likely future appearance of a more-advanced threat aircraft than an F-16 or F-4. The main consideration here is a stealthy aircraft design. Such a design will present a radically different set of electromagnetic and optical signatures in an engagement than a conventional fighter aircraft. The Task Force believes this is a valid concern, and recommends we begin the first steps in the development of a suitable test target. There are a number of approaches to fulfilling this need; an example approach is depicted in Figure 4. Such a design could embody a variety of low-observable characteristics as built-in features or add-on features. There are undoubtedly other approaches, and the services should begin a preliminary investigation of such options and plan to proceed into development soon.



<u>BAE/Scaled Composites, Inc.</u>
Unmanned, remotely piloted, blended wing-body configuration and all composite airframe using a P&W F100-200 engine

<u>Dimensions & Weight</u>
- **Length: 54 ft**
- **Wing span: 27 ft**
- **Wing area: 400 sq ft**
- **GTOW: 24,000 lbs**
- **Internal fuel: 8,000 lbs**
- **Payload: 2,500 lbs**

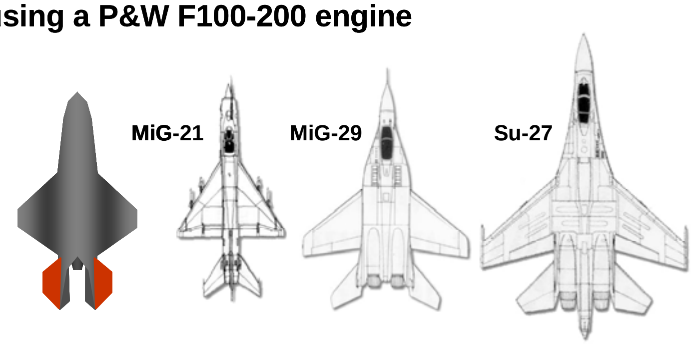


Figure 4. One Possible Future Target

Recommendations on Full-Scale Targets

1. **Immediately develop a drone replacement for the QF-4 using an existing aircraft platform. Seek to eliminate requirements for man-rating.** ***(U.S. Air Force)***

   The Task Force views this as a straightforward process that will fill our mid-term needs. The Task Force sees little need for lengthy investigations, so no gap in our mid-term capability should occur.

2. **Immediately begin a concept demonstration of a new, unmanned, full-scale drone that can capture important features of advanced fighter-size aircraft.** ***(U.S. Air Force)***

   A modest investment here will serve to sort out the possible approaches and put us on a path to produce the next-generation full-scale drone to deal with testing against advanced aircraft.

Supersonic Cruise Missiles

The Task Force found that our greatest deficiency is in aerial targets that emulate foreign supersonic cruise missiles designed for anti-ship missions. A substantial collection of such missiles has already been deployed by Russia and possibly other nations. Our development of test targets is markedly late in providing test vehicles for our weapons systems. This deficiency involves three major activities in supersonic vehicles that include both sea-skimming and high-altitude threats.

Supersonic Sea-Skimming Anti-Ship Target

Figure 5 summarizes the status of the GQM-163A development program. The development program has had a number of failures, but some recent successes (see Figure 6) led to a decision to proceed to limited production based on the Navy's critical need for testing against this class of threat. The Task Force supports this approach because the need here is dire.

Status: Being developed by the Navy as the principal supersonic sea-skimming target. Solid fuel ramjet-Mach 2.7

Unit Cost: $1600 K

Current Inventory: 0 (in development)

Current Expenditure Rate: 0, expected to be 10-15 per year

Production Status: LRIP-I: 10 units FY-05 and LRIP-II: 10 units FY-06

Figure 5. Supersonic Sea-Skimming Target GQM-163A

Figure 6. GQM-163A Flight over Mobile Surface Target

Supersonic "High-Diver" Target

The Russians have deployed a supersonic, high-altitude, anti-ship cruise missile whose flight profile involves a powered dive to the target. The Russians also produce an aerial target called the MA-31 that replicates the flight profile of the missile. Figure 7 gives the status of the MA-31.

The U.S. process to purchase these missiles is "stalled," and the future of the existing process is uncertain. The Russian bureaucracy is complex, and approval for the sale has likely been influenced by the often-changing political climate between the U.S. and Russia.

The Task Force supports our continuing attempts to purchase these vehicles, but we saw no backup plan if our purchase efforts are unsuccessful. We have vehicles that fly supersonically at high altitude (e.g., AQM-37C, see Appendix D); however, they cannot execute a powered-dive, and that part of the trajectory is critical to realistic testing. A backup plan is needed.

<u>Status</u>: MA-31 is a Russian high-altitude, supersonic anti-ship cruise missile aerial target with a powered dive to the target. (Since 1995, the Navy has purchased 18 and flown 13.)

<u>Unit Cost</u>: $840 K

<u>Current Inventory</u>: 2

<u>Current Expenditure Rate</u>: 0, expected rate is 5 per year

<u>Production Status</u>: In production in Russia – U.S. plan is to buy 41 vehicles.

<u>Issue</u>: Can bureaucratic, political hurdles be overcome to allow continuing U.S. purchase of MA-31s? If unsuccessful, what is the backup plan?

Figure 7. Supersonic Target ("High Diver") MA-31

Threat D – A Unique Subsonic-Supersonic Cruise Missile Threat

The Russians have developed and deployed a sea-skimming anti-ship cruise missile with a unique flight profile. Figure 8 illustrates this flight profile of the so-called "Threat D." The missile's flight starts as a subsonic cruise missile, but at a distance of some 20 km or so from its intended target, the front end of the cruise missile separates and begins a supersonic, sea-skimming dash to the target. The challenge for the U.S. weapon system engaging this target is to successfully track the warhead-containing vehicle through this transition and to rapidly recognize the increase in target velocity and accurately adjust the "launch-now" intercept point if the missile has not been launched or the predicted intercept point if the missile is in the air. This is a non-trivial job for the U.S. weapon system's tracking, guidance and engagement logic hardware and software, and full-scale testing against the complete flight trajectory regime is needed to assure that a workable scheme has been developed and perfected.

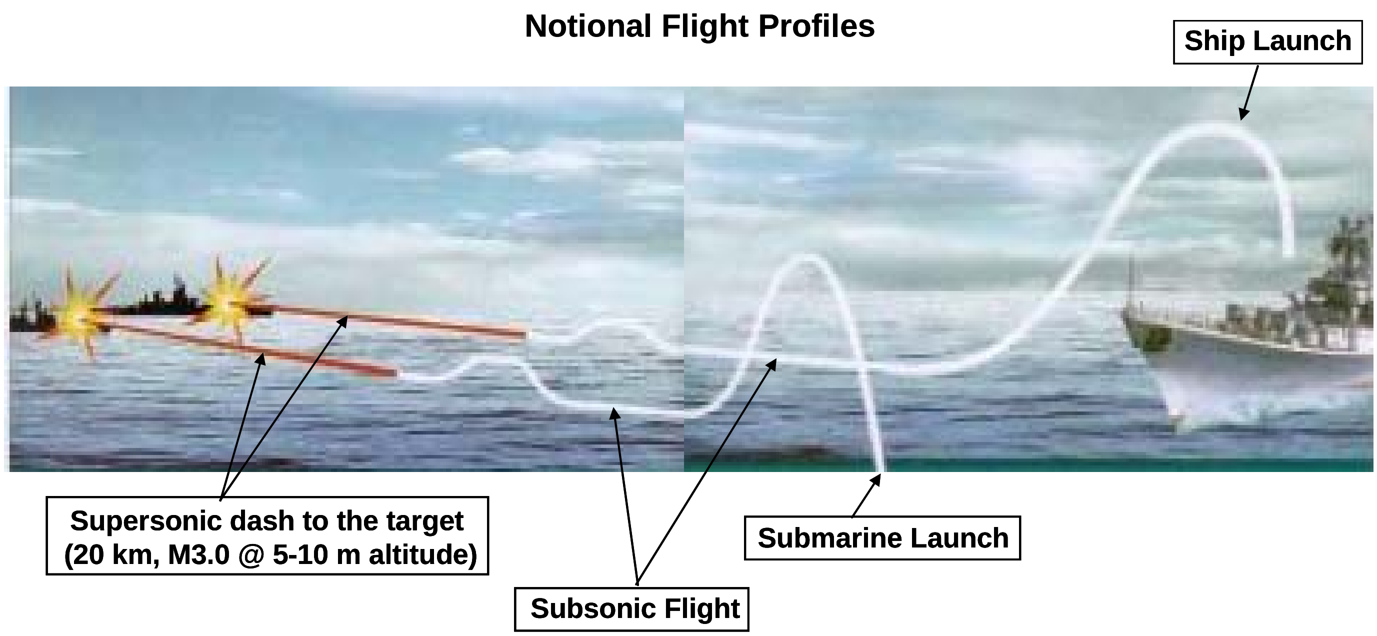
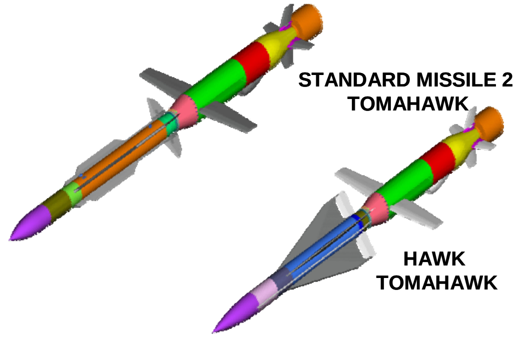


Figure 8. Unique Subsonic – Supersonic Missile: Threat D

Figure 9 gives the status of our efforts on Threat D. The Applied Physics Laboratory of Johns Hopkins University investigated the use of existing U.S. hardware to build a surrogate target with a Threat D-like flight profile. They concluded that a Tomahawk cruise missile with a Standard Missile or a Hawk missile front end could come close to emulating a Thread D flight profile. The Task Force envisions a "skunk works" style project* where a number of such surrogate vehicles can rapidly be

* "Skunk works style" implies a non-traditional acquisition of a limited number of air vehicles. The process should be rapid and streamlined; a process where the executing contractor is given a fair degree of decision-making authority and where government involvement is subdued.

Threat-D



JHU/APL Study Concepts

Status: Threat-D is a sea skimming anti-ship missile with a unique two-stage subsonic-supersonic flight profile. Studies are underway to assess possible U.S.-built surrogates.

Unit Cost: Uncertain; development cost is uncertain; $45 M RDT&E in budget

Current Inventory: 0

Current Expenditure Rate: 0, expected rate is 8 per year

Production Status: 0

Figure 9. Threat-D Status

assembled and tested. Testing against these vehicles would give us early insight into handling the unique Threat D flight profile.

Recommendations – Supersonic Cruise Missiles

The Task Force believes we are substantially deficient in our ability to test our weapon systems against supersonic cruise missiles, and we need to accelerate our efforts in this area. These are obviously difficult targets to build, but they are certainly within the grasp of U.S. technology. Since the existence of the threat could not be more real and the lives of U.S. servicemen are at risk, this is a time for aggressive OSD and Navy management. The solution path is, in our view, obvious:

- **Produce the GQM-163A as the principal sea-skimming supersonic target. *(U.S. Navy)***

  The challenge of supersonic sea-skimmers lies in their very low altitude and very high velocity trajectory coupled with terminal maneuvers and possible electronic countermeasures. The GQM-163A will allow testing of these issues.

- **Continue attempts to acquire Russian MA-31 vehicles for the high-diver threat, but immediately develop a backup plan for development and production of a domestic vehicle for this role**. ***(U.S. Navy)***

The backup plan is sorely needed here, since the ability to buy MA-31s from Russia will probably remain an uncertain process.

- **Immediately initiate a limited production of a Threat D surrogate. A "skunk works" style approach is recommended.** ***(U.S. Navy)***

  We need to quickly "get our feet wet" in dealing with the unique trajectory of Threat D. We may find that this threat can be accommodated by only tracking-software changes in our weapon systems, and we may need only occasional tests against such a target.

The Task Force emphasizes that time is of the essence here; continued testing against supersonic cruise missiles is essential.

Target Control Systems

As illustrated in Figure 10, the Air Force at Tyndall AFB, the Navy at Point Mugu, and the Army at White Sands Missile Range and Fort Bliss employ specialized, one-of-a-kind instrumentation suites and target control electronics. As a consequence, interoperability between service test programs is limited, and individual user programs do not enjoy the degree of testing flexibility possible if service targets could be flown on all service ranges.

Air Force Tyndall AFB, FL	Navy Pt. Mugu, CA	Army	
		WSMR, NM	McGregor Range Ft. Bliss, TX
Gulf Range Drone Control System (GRDCS) 915 MHz Multi-Lat	Integrated Target Control System (ITCS) 4.4 - 4.8 GHz LOS Radar Track System for Navy Target Control (SNTC) 435 – 450 MHz GPS	Drone Formation Control System (DFCS) 915 MHz Multi-Lat 380 - 400 MHz (TTCS-U Data Link) GPS	Target Tracking and Control System (TTCS-U) 380 - 400 MHz GPS
BQM-34 MQM-107 BQM-167 QF-4	BQM-34 BQM-74	BQM-34 MQM-107 QF-4 QUH-1	BQM-34 MQM-107 QUH-1

NOTE:
1. **GRDCS & DFCS interoperable with Air Force targets except BQM-167A**
2. **DFCS is multi-data link**
3. **ITCS primary T&E but obsolete, SNTC primary training – unproven in T&E**

Figure 10. Existing Test Facilities and Control Systems

There has been a recent unsuccessful attempt to agree on a common test instrumentation suite for all three service ranges. Change is difficult to achieve due to:

- Cost
- Concerns about the risk of major change
- Local environment concerns such as radio frequency interference
- Specialized individual service needs
- The legacy of range personnel who are "tied" to their particular instrumentation suites.

Economies, efficiencies, and flexibilities in aerial target testing will accrue if we could introduce elements of a common control system at each major range, such that any service could "shoot any target on any range." A common control system would also allow a migration away from today's one-of-a-kind systems, which will become increasingly difficult to service, maintain, and upgrade. This would also facilitate better joint testing and training, in accordance with recent DoD emphasis.

The DoD Test Resource Management Center, DTRMC, seems to have a charter that would enable it to stimulate the migration to a common aerial testing instrumentation suite. Transition could be gradual, but service "buy-in" at the start is critical. If DTRMC cannot achieve that initial "buy-in," then the Task Force believes that the whole common-instrumentation enterprise cannot be successful and it should not be attempted.

Recommendation on Target Control Systems

DTRMC, working with the services, should develop and ensure support of a plan for transition to a common aerial target control system with the long-term goal of "shoot any target on any range."

Related Questions

The Terms of Reference for the Task Force posed four questions related to aerial targets and testing. The Task Force's response to these questions is given below:

The Role of Modeling and Simulation

Q*:* *"To what extent can modeling and simulation supplement live target testing and training?"*

A:

- Simulation cannot do it all: we must have some live flight tests with representative kinematics, target complexity, and a size scale that capture important guidance and lethality effects. Countermeasures need to be included.
- We need a proper balance between flight test and simulation – flight test establishes the validity of simulation, and simulation assesses capabilities that cannot readily be determined by flight test.

- That balance should shift in time – heavier on flight test in new developments and heavier on simulation for upgrades of mature systems.
- Current programs seem to follow this protocol and do make extensive use of modeling and simulation.
- A danger would be to rely too much on modeling and simulation.

The AMRAAM program offers a good example of the balance between digital models, simulations, and flight tests. AMRAAM throughout 17 years of improvement programs employed a variety of processes for testing, as shown in Figure 11. Early in the AMRAAM evolution, full-scale flight tests numbered close to 100 per year, as did captive carry (ACE) tests. Digital simulation was initially limited, partially due to the immature state of digital simulation in the 1981 era. But today the simulation processes dominate AMRAAM testing, and full-scale flight tests number less than 10 per year. We see this evolution as a naturally-occurring engineering approach where, as we become more familiar with a system and its response to a wide variety of engagement situations, we are more confident in relying on digital simulations and less on full-scale tests.

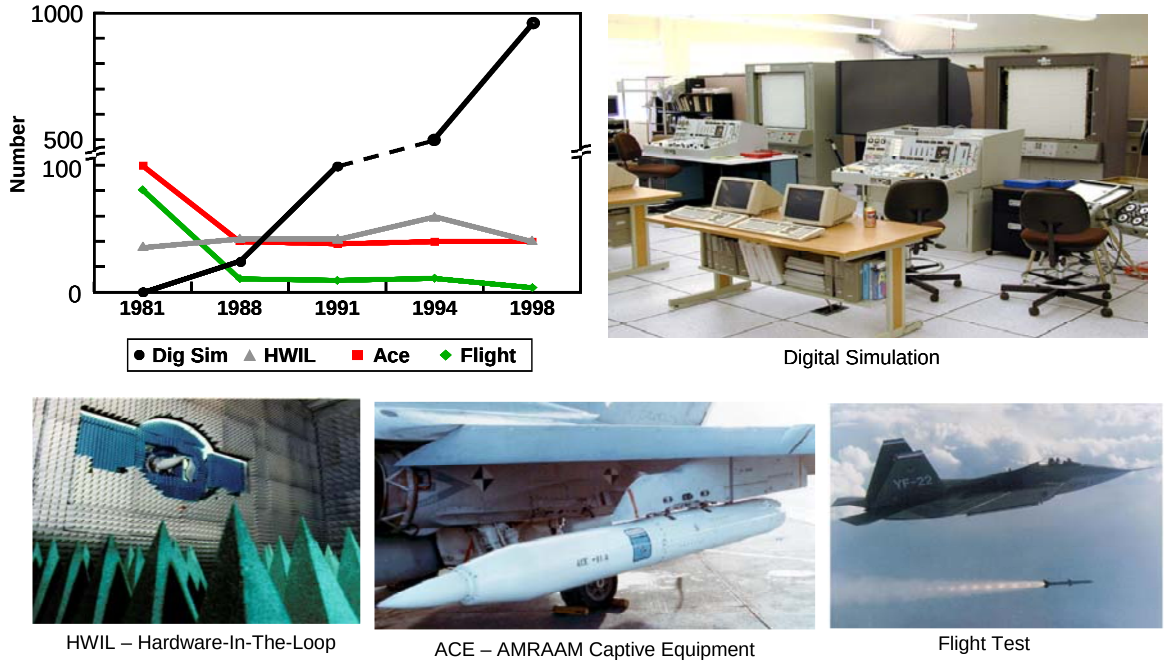


Figure 11. Simulation and Models in AMRAAM Development and Test

The Task Force believes that the increasing sophistication and capability of digital simulations will naturally result in their ever-wider use in weapon system developments. Our concern here is that we might become overly-enamored with digital simulations and tend to reduce the more expensive and difficult flight testing too much. Simulations are good only so long as they model reality – it is the flight tests that capture and provide that reality.

Common Target Configuration

Q: **“***Can a common target configuration support the testing needs of multiple systems, multiple services?”*

A:

- Funding constraints allow no choice but to do this.
- It is routinely done now (e.g., QF-4, MQM-107)
- There should be an assessment by the Army and Navy of their future use of the Air Force’s BQM-167A

Replication of Total Threat Flight Profile

Q: *Does a target need to replicate the total threat flight profile or only portions of it?”*

A:

- In general, part(s) of the flight profile should be adequate, because in most cases the weapon systems don’t see the full flight profile.
- But, if a threat has unique flight features, such as Threat D, that are observable by the weapon systems, then those flight features need to be represented in testing.

Degree of Fidelity in Threat Representation

Q*:* *“What degree of fidelity is required in threat representation?”*

A:

- We generally have only limited information on existing threats. Export models, various upgrades, and countermeasures add substantial uncertainty.
- We generally have far less information on threats in development.
- And we are often unaware of on-board countermeasures that can dominate the nature of an engagement.
- Thus, we are unlikely to ever achieve an exact representation, and we would be unwise to try.
- We should, therefore, test against generic representations of the threat, provide a rich set of dynamics and signature variations, and include countermeasures.

Helicopter and UAV Aerial Targets

The Task Force did not become substantially involved in helicopter or UAV target issues.

With regard to helicopters, there is a surprising dearth of testing against helicopter targets. The Army has some 20 UH-1 drone helicopters, which are expensive to maintain and are being mothballed. OSD DOT&E is funding an Army-led, tri-service analysis of helicopter target needs in 2006. The results of this assessment will be an important guidepost for rejuvenating testing against helicopter threats.

Testing against UAV targets will become increasingly important. The Army is procuring a small, inexpensive ($10K) UAV for testing. Other services can use this target or purchase appropriate vehicles from a diverse spectrum of available UAVs.

Management Planning and Oversight

The Task Force sees a need for a more-centralized management of the aerial targets area. We see evidence of this need in our existing gap in supersonic test targets and our approaching gap in full-scale targets. The desired migration to a common target control system will also require a focused and persuasive management.

The DoD Test Resource Management Center (DTRMC) seems ideally suited to this planning and oversight task.

Recommendation

The USD(AT&L) should clarify that the DTRMC charter includes aerial targets and their control systems. The USD(AT&L) should direct DTRMC to take on the corporate, long-range planning for aerial targets and target control systems.

Recommendation Summary

The Task Force's major recommendations are summarized below:

- **Proceed with a replacement for the QF-4 with an existing aircraft platform. Strive for non-man-rated vehicle. Develop a new target to represent likely future threats.** ***(U.S. Air Force)***

- **Proceed with aggressive efforts to develop and procure three types of supersonic anti-ship cruise missile targets (GQM-163A, MA-31, Threat D).** ***(U.S. Navy)***

- **Migrate to a common target control system and provide a centralized management and planning function to the aerial targets community.** ***(DoD Test Resource Management Center)***

Appendix A:

Terms of Reference

Appendix A: Terms of Reference

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

OCT 22 2004

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference—Defense Science Board Task Force on Test and Training Sub-scale and Full-scale Aerial Targets

You are requested to establish a Defense Science Board (DSB) Task Force on Test and Training Sub-scale and Full-scale Aerial Targets.

The increasing sophistication of aerial threats requires an assessment of future target resources necessary to support the test and training of systems developed to counter these future aerial threats. Options range from modeling and simulation to full combat system end-to-end testing using a variety of full-scale and sub-scale aerial targets. Each option poses specific challenges and limitations to test and training of new weapon systems.

The Task Force should assess:

- The future needs for sub-scale and full-scale aerial targets for developmental and operational testing. The Task Force should investigate future aerial threats as well as weapon and sensor capability in the 2005-2020 timeframe, to understand those characteristics necessary to provide effective threat representation.

- To what extent other alternatives including modeling and simulation can supplement live target testing and training.

- The possibility of common aerial target configuration, control and use that can support testing needs of more than one system or complex system of systems across multiple Services.

- If a particular target needs to replicate the total flight profile of a threat or only portions of that flight profile.

- The degree of fidelity in threat replication throughout the threat regime required for systems development and effective testing. The Task Force should consider testing needs across the full development cycle from concept development to operational test and evaluation and training.

- Specialized range, instrumentation, or facility requirements necessary for test and training against future aerial targets.

- Alternatives for replication of supersonic, sea-skimming threats, such as Threat D.

The study will be sponsored by me as the Acting Under Secretary of Defense (Acquisition, Technology and Logistics), Director, Defense Systems and Director, Operational Test and Evaluation. Mr. William Delaney and General Michael Williams, USMC (Ret) will serve as the Task Force Chairmen. Mr. Richard Lockhart, Deputy Director, Developmental Test and Evaluation, Defense Systems and Mr. Dennis Mischel, Program Manager, Targets Investment, Operational Test and Evaluation will serve as Co-Executive Secretary. CDR David Waugh will serve as the Defense Science Board Secretariat representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DOD Directive 5105.4, the "DoD Federal Advisory Committee Management Program," It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Michael W. Wynne
Acting

Appendix B:

Task Force Members

Appendix B: Task Force Members

Co-Chairmen

Gen Michael Williams, USMC, (Ret.), *Logistics Management Institute*
Mr. William Delaney, *MIT Lincoln Laboratory*

Members

Dr. David Kalbaugh, *JHU Applied Physics Laboratory*
Mr. Chester Kurys, *MIT Lincoln Laboratory*
Dr. George Schneiter, *Consultant*
Mr. Robert Stein, *Consultant*
Dr. Kyle Yang, *MIT Lincoln Laboratory*

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Dr. Steve Butler, *United States Air Force*
Mr. Edward Greer, *United States Navy*
Mr. Orville Hanson, *United States Navy*
Mr. Daniel Hicks, *United States Army*
Mr. Patrick Kearny, *United States Army*
Mr. Laurence Paulson, *Office of the Secretary of Defense*

DSB Secretariats

CDR Clifton Philips, *United States Navy*
Lt Col David Robertson, *United States Air Force*
CDR David Waugh, *United States Navy*

Executive Secretaries

Mr. Richard Lockhart, *Office of the Secretary of Defense*
Mr. Dennis Mischel, *Office of the Secretary of Defense*

Task Force Support

Ms. Diana Conty, *SAIC*
Mr. Michael Osborn, *SAIC*
Mr. Joseph Terlizzese, *SAIC*

Appendix C:

List of Briefings Received

Appendix C: Briefings Received

December 6

DT&E Aerial Targets Overview [Rick Lockhart, OSD-AT&L]

Intelligence Brief on Future Threats [National Air and Space Intelligence Center and Office of Naval Intelligence]

- Worldwide Cruise Missile Threat
- Anti-Ship Cruise Missile Threat (including Threat D) [ONI]
- Land Attack Cruise Missile Threat [NASIC]
- Worldwide Fighter Aircraft Threat [NASIC]
- UAV/UCAV Threat [NASIC]
- Airborne Threat Electronic Warfare/Countermeasures [NASIC]

DOT&E AT Overview [Dennis Mischel, OSD-DOT&E]

December 7

Army View on AT [Steve Milburn, US Army Target Management Office]

Air Force View on AT [Doug Nation, US Air Force Targets PM Office]

Navy View on AT [CAPT Rich Walter, US Navy, PMA-208]

Multi-Service Target Control System (MSTCS) [Derek Hinton, OSD-DOT&E, Central Test and Evaluation Investment Program]

December 8

Probability of Raid Annihilation (P_{RA}) M&S (Navy) [CAPT Rob Shafer, US Navy, PEO IWS 1D]

Threat D Studies (JHU/APL) [Roger Caldow, Johns Hopkins University/Applied Physics Laboratory]

January 5

Self Defense Test Ship – Overview [CAPT Shafer, US Navy, PEO IWS 1D]

NAVSEA Weapons Programs – Threat and Aerial Targets [US Navy, PEO IWS]

DoD Test Resource Management Center (DTRMC) [Dr. John Foulkes, Defense Test Resource Management Center]

AMRAAM – Threat and Aerial Targets [Mr. Kenneth Watson, US Air Force, AAC/YAE Counterair JSPO]

AMRAAM – Modeling and Simulation [Mr. Kenneth Watson, US Air Force, AAC/YAE Counterair JSPO]

January 6

Joint Strike Fighter (JSF) – Threat and Aerial Targets [Maj Timothy Chong, USAF, JSF JPO]

Joint Strike Fighter (JSF) – Modeling and Simulation [CDR Patrick Porter, USN, JSF JPO]

AIM-9X – Threat and Aerial Targets [CAPT Stewart, US Navy, NAVAIRSYSCOM]

AIM-9X – Modeling and Simulation [CAPT Stewart, US Navy, NAVAIRSYSCOM]

February 8

Self Defense Test Ship – T&E Results [CAPT Rob Shafer, US Navy, PEO IWS 1D]

Threat D Analysis [CAPT Rob Shafer, US Navy, PEO IWS 1D]

Aerial Superiority Target (AST) – Required Threat Performance [Mr. Dennis Mischel, OSD-DOT&E]

F/A-22– Threat and Aerial Targets [Lt Col Andrew Thurling, US Air Force]

F/A-22– Modeling and Simulation [Lt Col Andrew Thurling, US Air Force]

PAC-3/MEADS – Threat and Aerial Targets [Larry Hoffmeister, US Army AMCOM, Lower Tier Air and Missile Defense Project Office]

PAC-3/MEADS – Modeling and Simulation [Larry Hoffmeister, US Army AMCOM, Lower Tier Air and Missile Defense Project Office]

February 9

ATEC – Current and Future Aerial Target Test Limitations [Mr. Paul Kelley, US Army, Army test and Evaluation Command]

COMOPTEVFOR – Current and Future Aerial Target Test Limitations [Mr. Lou Lassard, US Navy, COTF 01B5]

AFOTEC – Current and Future Aerial Target Test Limitations [Mr. Paul Holt, US Air Force, AFOTEC/TST]

March 14

Point Mugu Welcome and Capability Overview [Captain Mark Swaney, USN, Vice Commander, NAWCWD]

Target Operations Overview and Facility Tour [Mr. Paul McQuaide, Mr. Bob Williams, US Navy, NAWCWD]

March 15

Sparrow/ESSM Hardware-in-the-Loop (HIL) Laboratory Facility Tour [Mr. Mike Safty, US Navy, NAWCWD]

Airborne Threat Simulation Overview and Facility Tour [Mr. Ben Rasnick, US Navy, NAWCWD]

Target Control Briefing [Mr. Mike Mentas, US Navy, NAWCWD]

April 13

Target Control Industry [Mick Owens, Herley/MSI]

Target Control Industry [Albert Sulmistras, CDL]

Air Force Target Control Systems [Jim Moore, US Air Force 53rd Weapons Evaluation Group]

Army Target Control Systems [Martin Maese, WSMR; Dennis Brooks, US Army STRICOM]

Air Superiority Technical Requirements [Dennis Mischel, DOT&E]

AMRAAM Modeling and Simulation Evolution [Steve Butler, US Air Force AFMC/EN]

April 14

Directed Energy Aerial Target Requirements [James Brogdon, AF/TEP; Col Tom Buter, AFRL/DE; Dr. Hank Dubin, DUSA(OR); Charles Buchanan, Navy; Dr. Randall Thompson, MDA/TEX]

May 18

Air Force Academy's Technical Review of Design Concept Alternatives to the QF-16 [Dr. Brandt, US Air Force Academy]

Appendix D:

Compendium of Aerial Targets

Chester J. Kurys

Appendix D: Compendium of Aerial Targets

Chester J. Kurys

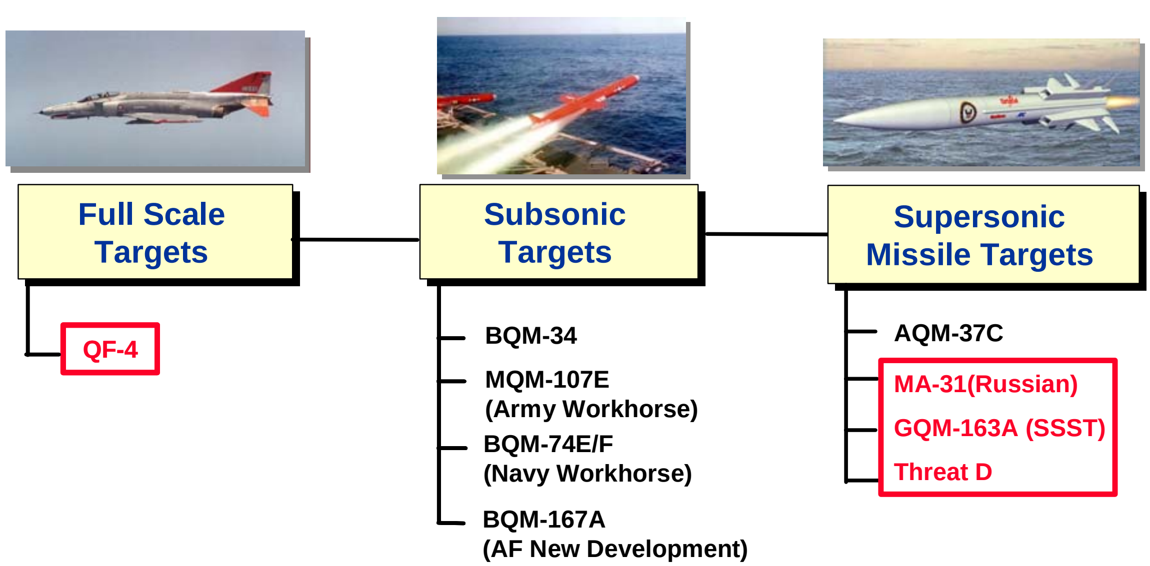
This appendix contains an overview of the aerial targets considered during the deliberations of this Task Force. We have included some pertinent information on each aerial target that was current as of May 2005.

Not all of the aerial targets presented in this appendix are discussed in the main body of the report. Some targets did not present any major issues of concern to the Task Force. The targets shown with a box around them were discussed in the main report. All targets are included here to provide a single place where information on the aerial targets can be found.

The presentation is in the following order and follows the flow on the following figure. The QF-4 full scale target is presented first followed by a possible future composite airframe that might be representative of advanced threats. Information is included on a Lockheed Martin proposed droned F-16 that would be called QF-16, a possible replacement for the QF-4. Then, the subsonic aerial targets are presented; concluding with the supersonic targets.

Included is information gathered from open sources on Threat-D, a Russian sea-skimming missile with a unique subsonic-supersonic flight profile.

Principal Aerial Targets



Full Scale Aircraft Target
QF-4 Drone

Status: Only full-scale target – inventory will be depleted about 2011

Unit Cost: $2300 K

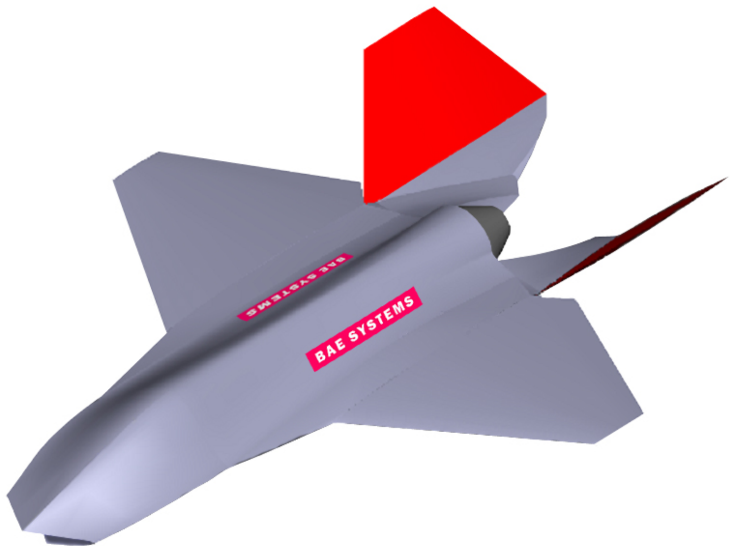
Current Inventory: 53

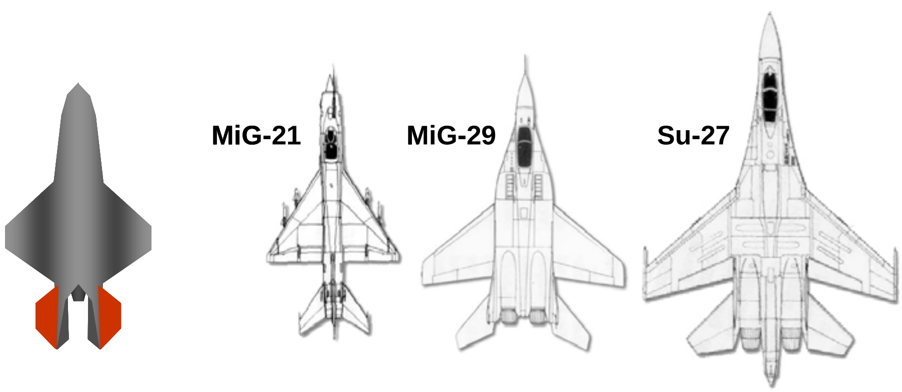
Current Expenditure Rate: 25 per year (across all three services)

Production Status: About 150 QF- 4s produced in the past – current production program: 20 per year

Issue: DoD needs to decide on a replacement vehicle and start production. Does the drone have to be “man-rated”? (A major cost driver)

One Possible Future Target





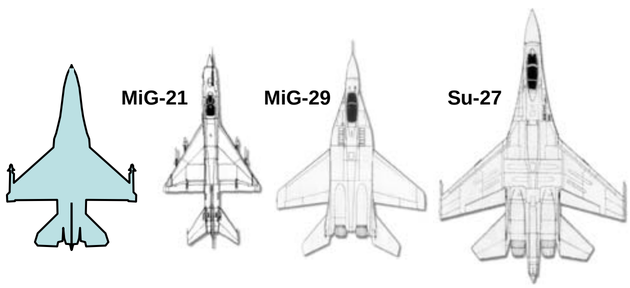
<u>BAE/Scaled Composits, Inc.</u>

Unmanned, remotely piloted, blended wing-body configuration and all composite airframe using a P&W F100-200 engine

<u>Dimensions & Weight</u>

- Length: 54 ft
- Wing span: 27 ft
- Wing area: 400 sq ft
- GTOW: 24,000 lbs
- Internal fuel: 8000 lbs
- Payload: 2,500 lbs

Lockheed Martin Proposed QF-16



General

- Block 10/15 from AMARC
- Drone Conversion
- P&W F100-200 or -220 engine
- Performance of current & future
- Relatively High RCS

Dimensions & Weight

- Length: 49.5 ft
- Wing span: 31 ft
- Wing area: 300 sq. ft
- GTOW: 28,000 lbs
- Internal fuel: 7,000 lbs
- Payload: 2,500 lbs (external)

Sub-Sonic Target
BQM-34

Status: Navy addressing obsolescence issues; installing upgraded integrated avionics unit to make common with BQM-74E/F

Unit Cost: $897 K

Current Inventory: 8 Army, 213 Navy, 52 Air Force

Current Expenditure Rate: 1-2 Army, 4 Navy, 11 Air Force

Production Status: Out of production. Navy in sustainment

Issue: Replacement when inventory runs out?

Subsonic Target
MQM-107E

Status: Principal cruise missile target used by the Army as a target for Patriot PAC-2 & PAC-3, Improved Hawk and Stinger. Also used by the US Air Force for AIM-9 Sidewinder, AIM-7 Sparrow and AIM-120 AMRAAM testing.

Unit Cost: $238 K

Current Inventory: 130 (12 USAF, 118 Army)

Current Expenditure Rate: 44 per year including FMS

Production Status: 1018 MQM-107s produced in the past – no current production program, but production is traditionally intermittent

Issue: None

Subsonic Target
BQM-74E and BQM-74F

BQM-74E

BQM-74F

Status: Principal subsonic anti-ship cruise missile target used by the Navy

Unit Cost: $342 K (BQM-74-E), $387 K (BQM-74F)

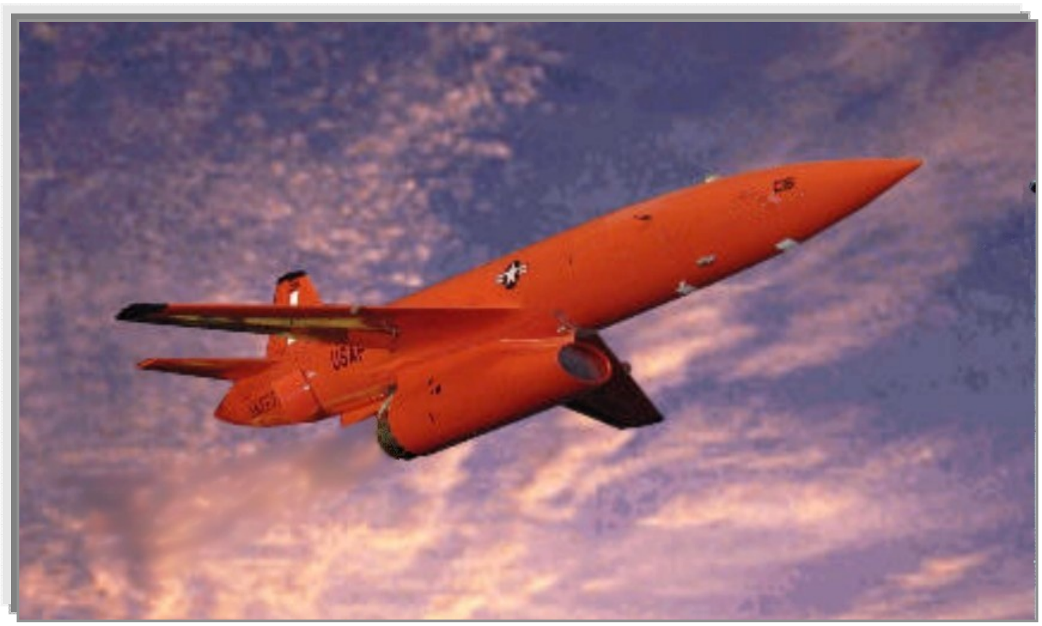
Current Inventory: 202 BQM-74Es

Current Expenditure Rate: 60 per year

Production Status: 1787 BQM-74s produced in the past. Current program to produce 60 “E” models. BQM-74F production of 60 to start FY06.

Issue: None

Subsonic Target
BQM-167A (AFSAT*)



<u>Status</u>: Being developed by USAF as their principal subscale, subsonic target. Longer endurance than BQM-74s or MQM-107s.

<u>Unit Cost</u>: $574 K

<u>Current Inventory</u>: 6 development models

<u>Current Expenditure Rate</u>: 40 per year expected

<u>Production Status</u>: Planning for 40 per year starting January 2007. LRIP-II ongoing for 10- units.

<u>Issue</u>: Will there be any Army or Navy participation in this program?

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* Air Force Subsonic Aerial Target

Supersonic Target
AQM-37C

Status: Foreign military sales comprise approximately 30 - 50% of operations per year. Maximum speed is Mach 4 @ 100 kft. In dive, AQM-37C goes subsonic by ~30 kft.

Unit Cost: $146 K

Current Inventory: 223

Current Expenditure Rate: 10 per year (Navy)

Production Status: Out of production - in sustainment

Issue: Cannot perform powered dive.

Supersonic Target ("High Diver")
MA-31

Status: MA-31 is a Russian high-altitude, supersonic anti-ship cruise missile aerial target with a powered dive to the ship target. (Since 1995, the navy has purchased 18 and flown 13.)

Unit Cost: $840 K

Current Inventory: 2

Current Expenditure Rate: 0, expected rate is 5 per year

Production Status: In production in Russia – U.S. plan is to buy 41 vehicles.

Issue: Can bureaucratic, political hurdles be overcome to allow continuing U.S. purchase of MA-31s? If unsuccessful, what is the backup plan?

Supersonic Sea Skimming Target
GQM-163A

Status: Being developed by the Navy as the principal supersonic sea-skimming target. Solid fuel ramjet – Mach 2.7

Unit Cost: $1600 K

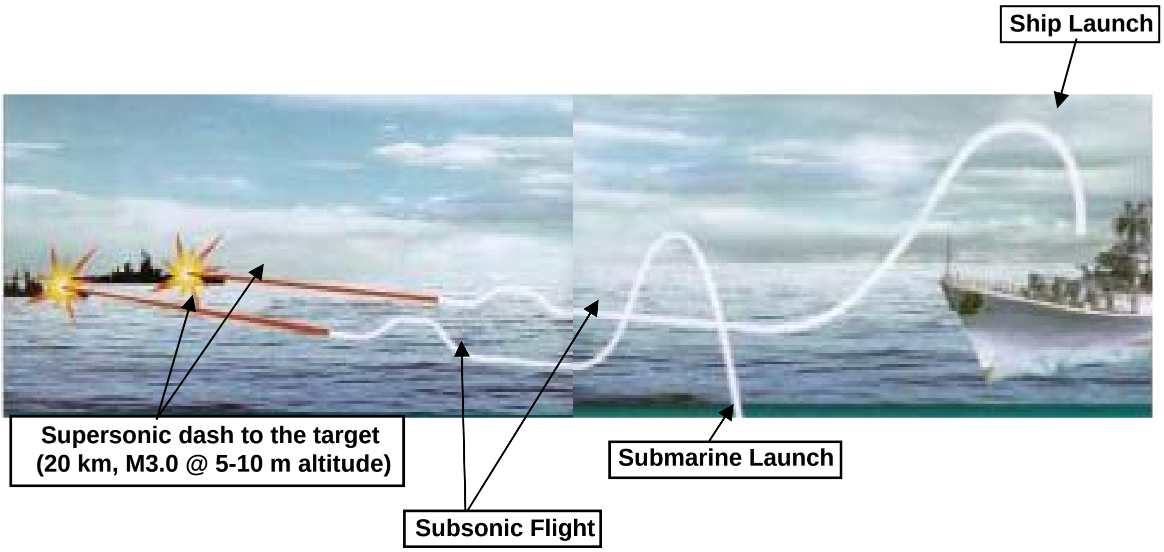
Current Inventory: 0 (in development)

Current Expenditure Rate: 0, expected to be 10-15 per year

Production Status: LRIP-I: 5 units Aug – Sep 05; 5 units May – Jun 06;
LRIP-II: 10 units; 1 per month beginning in May 06.
Note: Contract allows for early delivery.

Issue: Program risk remains. Development program had a number of test flight failures. Decision was made to move into limited production due to the pressing Navy need to test against supersonic sea skimmers.

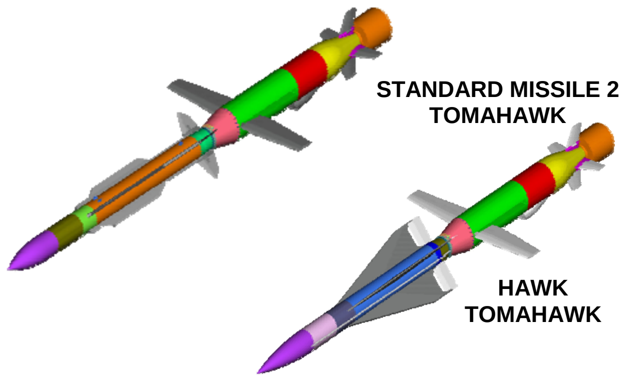
Unique Subsonic – Supersonic Target: Threat – D



Shown above are two notional flight profiles. The missile can be launched either from a surface ship or a submarine. It climbs in altitude where the solid booster separates from the missile and bus. It then dives to low altitude (20 meters) for a sea skimming subsonic flight towards the target. It can pop up to perform a radar search for the target and then return to low altitude until it is about 20 km from the target. At this point, the combat stage separates from the bus. The bus falls away and the missile makes a supersonic dash to the target at Mach 3.0 at an altitude of 5 to 10 meters.

Subsonic – Supersonic Target

Threat-D



JHU/APL Study Concepts

Status: Threat – D is a sea skimming anti-ship missile with a unique two stage subsonic-supersonic flight profile. Studies are underway to assess possible U.S.-built surrogates.

Unit Cost: Uncertain; development cost is uncertain; $45 M RDT&E in budget

Current Inventory: 0

Current Expenditure Rate: 0, Expected rate is 8 per year

Production Status: 0

Issue: Urgent need to decide on an appropriate surrogate and proceed to production. Nature of effort to be decided: conventional vs. “skunk works”.

Appendix E:

List of Acronyms

Appendix E: List of Acronyms

AEGIS	US Navy phased array radar-based combat system
AMRAAM	Advanced Medium-Range Air-to-Air Missile
DFCS	Drone Formation Control System
DoD	Department of Defense
DOT&E	Director of Operational Test and Evaluation
DSB	Defense Science Board
DTRMC	DoD Test Resources Management Center
GRDCS	Gulf Range Drone Control System
ITCS	Integrated Target Control System
OSD	Office of the Secretary of Defense
RDT&E	Research, Development, Test and Engineering
SNTC	System for Navy Target Control
TOR	Terms of Reference
TTCS-U	Target Tracking and Control System
UAV	unmanned aerial vehicle
U.S.	United States
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics