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Adequately Resourcing and Optimizing Efficiency for Test and Evaluation in Marine Corps Aviation

June 2023

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Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

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ABSTRACT

This capstone applied project examines Marine Operational Test and Evaluation One (VMX-1) to determine ways to optimize efficiency and determine additional test capacity for the squadron. The squadron conducts operational test and evaluation (OT&E) for AH-1Z, CH-53K, F-35B, MV-22B, and UH-1Y aircraft, as well as numerous other projects for the Marine Corps under the Tactics and Integration Department. This project examines each of the resource shortfalls the squadron faces to identify the underlying issues affecting the squadron's ability to complete its mission. The data used to make a conclusion includes evaluating the process flow to conduct OT&E as well as analyzing recently completed projects for the AN/APR-39D(V)2 Radar Warning Receiver for the MV-22 and the Joint Air-to-Ground Missile for the AH-1Z. The project recommends improving training and billet tenure for Operational Test Directors, improving the scheduling tool to improve communication within the squadron, and scrutinizing emerging test systems for potential entry into the abbreviated acquisition framework.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAF	Adaptive Acquisition Framework
ACAT	Acquisition Category
ACE	Aviation Combat Element
ADT&E	Aviation Development Tactics and Equipment
AFB	Air Force Base
AWG	Analysis Working Group
B&G	Blue and Gold
BIC	Billet Identification Code
C2	Command and Control
C5ISRT	Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, Reconnaissance, and Targeting
CBTE	Capabilities-Based Test and Evaluation
CCRM	Core Competency Resource Model
CE	Command Element
CEWG	Critical Operational Issues Evaluation Working Group
CMC	Commandant of the Marine Corps
COI	Critical Operational Issue
COMOPTEVFOR	Commander, Operational Test and Evaluation Forces
CONUS	Continental United States
DCA	Deputy Commandant for Aviation
DCP	Data Collection Plan
DI	Digital Interoperability
DOD	Department of Defense
DON LAIRCM	Department of the Navy Large Aircraft Infrared Countermeasures
DOT&E	Director of Operational Test and Evaluation
DOTmLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
DT	Developmental Test
F/AD	Force or Activity Designator
FOC	Full Operational Capable

FOT&E	Follow-on Test and Evaluation
FY	Fiscal Year
GAO	Government Accountability Office
GCE	Ground Combat Element
HQMC	Headquarters Marine Corps
IEF	Integrated Evaluation Framework
I-Level	Intermediate Level
IOC	Initial Operations Capable
IOT&E	Initial Operational Test and Evaluation
IPR	In-Process Review
JAGM	Joint Air-to-Ground Missile
JPO	Joint Program Office
JTF	Joint Task Force
LCE	Logistics Combat Element
LRPC	Long-Range Planning Calendar
LTD	Level of Test Determination
MAG	Marine Aircraft Group
MAGTF	Marine Air-Ground Task Force
MARADMIN	Marine Administrative Message
MAW	Marine Aircraft Wing
MAWTS-1	Marine Air Weapons and Tactics Squadron One
MBTD	Mission-Based Test Design
MCAS	Marine Corps Air Station
MCDOA	Marine Corps Department of Aviation
MCOTEA	Marine Corps Test and Evaluation Activity
MCWL	Marine Corps Warfighting Lab
MDA	Major Defense Acquisition
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
MLG	Marine Logistics Group
MNM	Mesh Network Manager

MOS	Military Occupational Specialty
M-SHARP	Marine Sierra Hotel Aviation Readiness Program
NAVAIR	Naval Air Systems Command
NSI	Night Systems Instructor
O-Level	Organization Level
OPTEVFOR	Operational Test and Evaluation Forces
OT	Operational Test
OT&E	Operational Test and Evaluation
OTD	Operational Test Director
POI	Program of Instruction
QA	Quality Assurance
QRA	Quick Reaction Assessment
RSDS	Radar Signal Detection Set
RW/TR	Rotary-Wing/Tiltrotor
RWR	Radar Warning Receiver
SERB	System Evaluation Review Board
SPMAGTF	Special Purpose Marine Air-Ground Task Force
SUT	System under Test
T&E	Test and Evaluation
T&I	Tactics and Integration
T&R	Training and Readiness
T/M/S	Type/Model/Series
T/O	Table of Organization
TACAIR	Tactical Air
TECOM	Training and Education Command
TEEP	Training and Exercise Employment Plan
TOECR	Table of Organization and Equipment Change Request
TOS	Time on Station
TPS	Test Pilot School
TRL	Technology Readiness Level
TTP	Tactics, Techniques, and Procedures
UAS	Unmanned Aerial System

UND	Urgency of Need Designator
UOTT	United States Operational Test Team
VMM	Marine Medium Tiltrotor Squadron
VMX-1	Marine Test and Evaluation Squadron One
WTI	Weapons and Tactics Instructor

I. INTRODUCTION

With the return of the pacing threat competition with China and with Russia's continuing invasion of Ukraine, the Defense Acquisition System must continue to evolve new technologies and practices to allow warfighters to be prepared to fight with the most advanced equipment to protect American interests. The 2022 *National Defense Strategy* outlined the goal to "prioritize a future force that is lethal," "sustainable," "resilient," "survivable," "agile" and "responsive" (Department of Defense [DOD], 2022, p. 18). However, the document also discussed issues with transforming the future force.

> Building the Joint Force called for by this strategy requires overhauling the Department's force development, design, and business management practices. Our current system is too slow and too focused on acquiring systems not designed to address the most critical challenges we now face. This orientation leaves little incentive to design open systems that can rapidly incorporate cutting-edge technologies, creating longer-term challenges with obsolescence, interoperability, and cost effectiveness. The Department will instead reward rapid experimentation, acquisition, and fielding. We will better align requirements, resourcing, and acquisition, and undertake a campaign of learning to identify the most promising concepts, incorporating emerging technologies in the commercial and military sectors for solving our key operational challenges. We will design transition pathways to divest from systems that are less relevant to advancing the force planning guidance, and partner to equip the defense industrial base to support more relevant modernization efforts. (DOD, 2022, p. 19)

A. PROBLEM

Rapid experimentation, acquisition, and fielding requires heavy involvement from Operational Test and Evaluation (OT&E) personnel within the DOD. For Marine Corps Aviation, Marine Operational Test and Evaluation Squadron One (VMX-1) supports OT&E events under the different organizations depending on the system under test. The squadron, not unlike other units within the DOD, experiences challenges that make it difficult to identify how to best employ assets and determine the capacity to complete future projects.

B. RESEARCH QUESTIONS

1. Primary Research Question

- How should OT&E be adequately resourced in Marine Aviation, and what are the best ways to optimize efficiency to determine additional test capability for the squadron?

2. Secondary Research Questions

- Are there specific problem areas that would improve efficiency?
- How is the operational test (OT) planning process flow different from and/or similar to programs in each of the Adaptive Acquisition Framework (AAF) pathways?

C. WHY IS THIS RESEARCH IMPORTANT?

Delays in fielding emerging technology present two significant problems. Warfighters lack the advantage against foreign threats, and inadequately testing and evaluating systems increases the risk of failure to meet cost, schedule, and performance baseline requirements, increasing the financial burden to the American taxpayer. Effective OT&E is an integral part of the acquisitions process. Enhancing the capability of VMX-1 to determine the effectiveness and suitability of systems under test allows Marine Aviation to play a pivotal role in the future fight.

D. METHODOLOGY

This capstone applied project reviews literature on government publications, journal articles, previous Naval Postgraduate School theses, and government reports on the roles of test and evaluation (T&E) and delays with specific DOD programs. This document reviews reports from systems within VMX-1 and compares issues associated with conducting the testing through a root cause analysis. Additionally, resource shortfalls experienced by VMX-1 are examined to determine specific problem areas that would improve efficiency.

1. Scope

This capstone applied project examines projects and products submitted by VMX-1. The following chapters study the organizations references that establish the squadron and the units that support it, as well as the guiding doctrines that define the methods to conduct flight and maintenance operations. In the analysis section, unclassified information from OT reports have been summarized or quoted to identify issues related to the research questions.

2. Limitations

This report only focuses on VMX-1 and not the Marine Corps Operational Test and Evaluation Activity as a whole. Data for determining delays in testing have been compiled through the reports submitted from the squadron, and the reports discuss the deficiencies in the system rather than problems during the testing process.

E. CHAPTER SUMMARY

Near-peer global power competition exists, and successful OT&E ensures the right equipment is fielded to warfighters. With efficient OT&E, cost and schedule overruns may be reduced for programs. This chapter established the significance of OT&E for Marine Aviation and described the research questions for this capstone applied project. The following chapters will cover the background on the scope of OT&E for Marine Aviation, review pertinent literature on the topic, analyze the root causes of issues to optimize efficiency, and provide recommendations for improvement.

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II. BACKGROUND

This chapter examines the organization and roles of the Marine Corps, Marine Aviation, as well as the role VMX-1 plays to support OT&E and the Fleet Marine Force. With the understanding of how VMX-1 fits into Marine Aviation, further examination of the contributing factors to delays in test reporting can be explained.

A. ORGANIZATION OF THE MARINE CORPS

Marines, heralded as "first to fight," are a component of the Department of the Navy established under 10 U.S.C. § 8061. The Marine Corps supports the president and secretary of defense as a conventional force in readiness with combined arms Marine Air–Ground Task Forces (MAGTFs) that are scalable to conduct operations across the range of military operations (Headquarters United States Marine Corps [HQMC], 2015). The self-contained nature of the Marine Corps allows a unit to be expeditionary; a MAGTF is designed to be mission-specific and arrives at a location with a command element, Marines, logistics support, and aviation, if required, to be successful. This integrated, task-organized force provides a commander with what is called the "single-battle" concept (HQMC, 2018a). After the planned duration of the mission, the MAGTF turns over the area to other conventional forces, is reinforced, or returns and prepares for any other contingencies.

The MAGTF consists of four key elements, as depicted in Figure 1: the command element (CE), the ground combat element (GCE), the aviation combat element (ACE), and the logistics combat element (LCE). The CE is the headquarters unit and is "responsible for the command and control (C2), direction, planning, and coordination of air, ground, and logistic operations" (HQMC, 2015, p. 3-3). The GCE originates from an infantry regiment and is reinforced as required. The ACE is comprised of all the aviation assets and aviation support equipment to provide air support. (This will be examined more thoroughly in the next section.) The LCE is task-organized to support the logistics for the mission and the requirements generated from the other elements of the MAGTF.

The Fleet Marine Force is organized in three Marine expeditionary forces (MEFs), with headquarters located in Camp Lejeune, NC; Camp Pendleton, CA; and Okinawa,

Japan. The Marine Corps Reserve component has units spread around the United States and provides Marines to augment and reinforce active units. Figure 1 shows four subordinate commands of an MEF, the typical personnel requirement for each, and an example mission for which that size force would be created. The MEF is the principal Marine Corps warfighting organization, and "with appropriate augmentation, the MEF CE may serve as a joint task force (JTF) headquarters" (HQMC, 2015, p. 1-3). The Marine expeditionary brigade (MEB) is a MAGTF built around a reinforced infantry regiment, a Marine aircraft group (MAG), and components of a Marine logistics group (MLG). The Marine expeditionary unit (MEU) is formed on a rotational basis and is the standard forward-deployed Marine expeditionary organization. Finally, the Special Purpose MAGTF (SPMAGTF) is the catch-all unit, usually smaller than an MEU, which is selected from units to accomplish a specific mission.

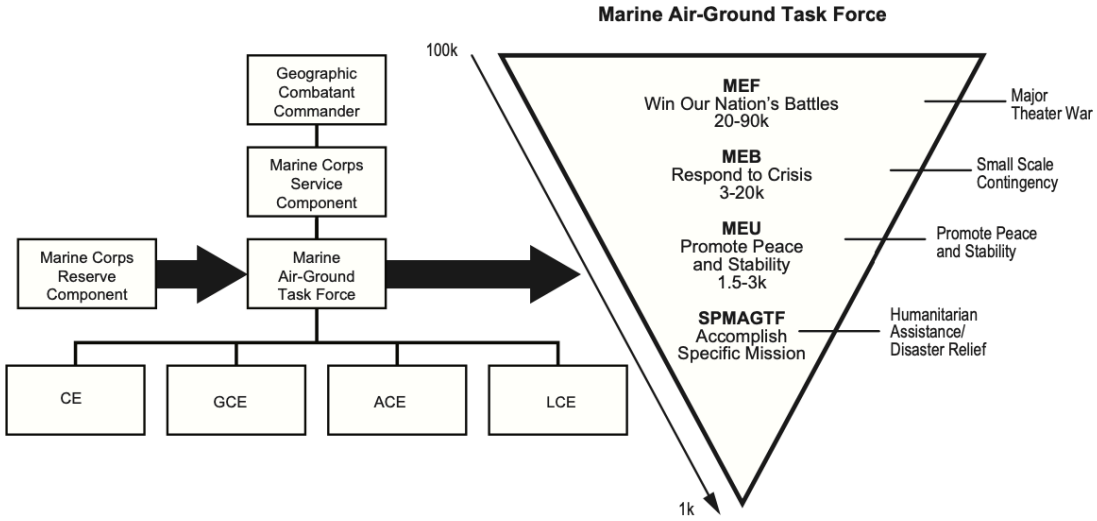

Figure 1. MAGTF Key Elements. Source: HQMC (2015, p. 1-4).

The SPMAGTF may have dedicated aviation assets and capability, but every size MAGTF above an SPMAGTF has an assigned aviation unit. The MEU has a Marine medium tiltrotor squadron (VMM) assigned with reinforcements generally attached from heavy-lift helicopters, attack and utility helicopters, fighter attack aircraft, unmanned aerial

vehicles, a C2 detachment, and logistics support. The MEB, when formed, uses the MAG as the assigned aviation component, with additional squadrons and aviation capabilities—including aerial refueling, transport aircraft, and greater aviation intelligence assets. For the MEF, the Marine aircraft wing (MAW) supports aviation functions, and in a nondeployed status, units within the MAW train to support the functions of Marine Aviation.

B. ROLE AND ORGANIZATION OF MARINE AVIATION

Marine Aviation extends the operational reach of the MAGTF beyond that of a solely land-based force and contributes to massing distributed effects across the naval expeditionary force (Marine Corps Department of Aviation [MCDOA], 2022).

> Functions that are common to joint operations at all levels of war fall into six basic groups—C2, intelligence, fires, movement and maneuver, protection, and sustainment. The joint functions reinforce and complement one another, and integration across the functions is essential to mission accomplishment. (Joint Chiefs of Staff [JCS], 2022, p. xiv)

Additionally, following the release of the commandant's vision for *Force Design 2030*, the deputy commandant for aviation (DCA) added four maritime aviation operations in the 2022 Aviation Plan—anti-submarine warfare, surface warfare, information operations, and intelligence, surveillance, and reconnaissance missions—and challenged Marine Aviation to develop new methods for sustaining stand-in, expeditionary airpower.

Marine Aviation defines its support through the lens of six defined functions. These functions include offensive air support, anti-air warfare, assault support, air reconnaissance, electronic warfare, and control of aircraft and missiles (HQMC, 2018a). Without going too far into the specifics of each function and the defined tasks that support them, these functions and their subcategories are listed in Figure 2.

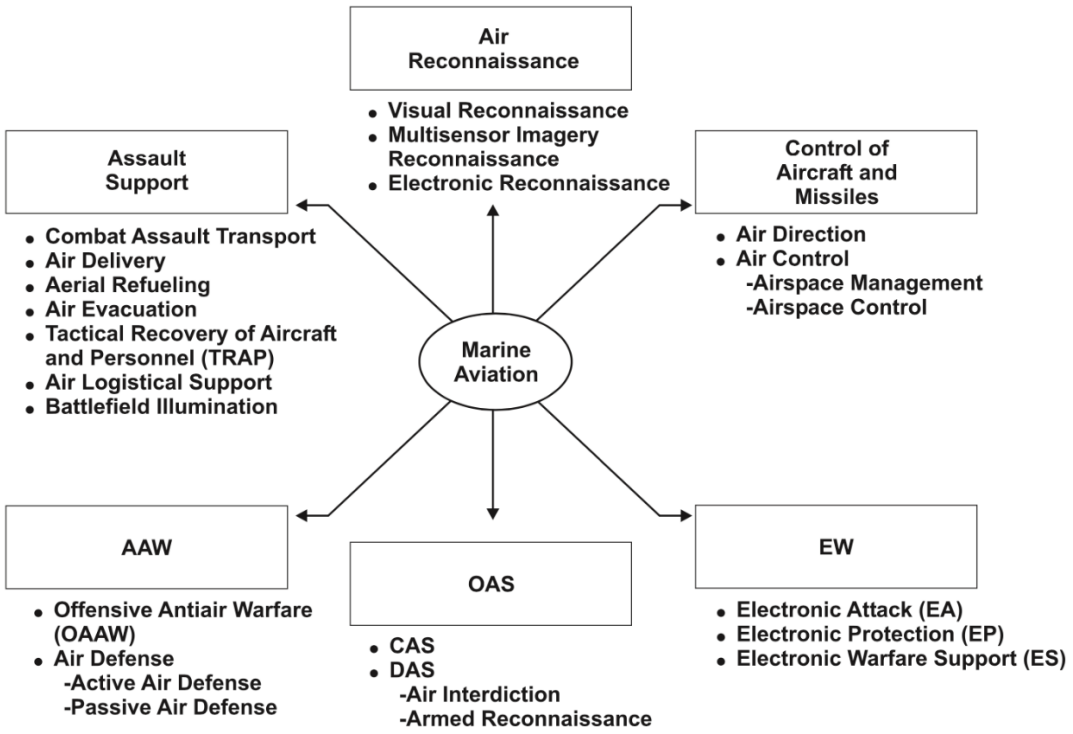

Figure 2. Six Functions of Marine Aviation. Source: HQMC (2018a, p. 2-2).

Each of the six functions of Marine Aviation are aligned to accomplish warfighting functions directly or to support the accomplishment. Table 1 defines the role of each function in relation to the warfighting functions defined in the Marine Corps doctrine for campaigning.

Table 1. Functions of Aviation in Support of Warfighting Functions. Source: HQMC (2018a, p. 3-11).

	Warfighting Functions and the Type of Support Provided					
Functions of Marine Aviation	**Command and Control**	**Maneuver**	**Fires**	**Intelligence**	**Logistics**	**Force Protection**
Assault Support	**Support**	**Primary**	**Support**	**Support**	**Primary**	**Support**
AAW	**Support**	**Support**	**Support**	**Support**	**Support**	**Primary**
Air Reconnaissance	**Support**	**Support**	**Support**	**Primary**	**Support**	**Support**
EW	**Support**	**Support**	**Primary**	**Primary**	**Support**	**Primary**
OAS	**Support**	**Support**	**Primary**	**Support**	**Support**	**Primary**
Control of Aircraft and Missiles	**Primary**	**Support**	**Support**	**Support**	**Support**	**Support**

Furthermore, Marine Aviation is also being reshaped in accordance with *Force Design 2030*. In this document, General Berger (2020) directed changes to the number and composition of squadrons. From the doctrinal perspective, the functions of Marine Aviation and their relation to a warfighting function does not specify the type of aviation unit or asset that will fulfill it. While slightly dated at this point, Table 2, adapted from Marine Corps Warfighting Publication 3-20, shows the type of squadron in the MAG and the support that the type of squadron provides to accomplish the function of Marine Aviation. Amplifying to this, Table 3 is compiled from the 2022 Aviation Plan and shows the current and projected alignment of squadrons and aviation assets in the Marine Corps inventory. Referencing between the tables allows the reader to determine which type/ model/series (T/M/S) platform the ACE will use to accomplish a specified aviation function with the existing or funded aircraft inventories.

Table 2. Marine Aviation Units and Functions. Adapted from HQMC (2018a, p. 2-7).

Type of Aviation Unit	AAW	Assault Support	OAS	EW	Air Reconnaissance	Control of Aircraft and Missiles
MAW Marine Aircraft Wing	X	X	X	X	X	X
MACG Marine Aircraft Control Group	Support	Support	Support	Support	Support	X
MTACS Marine Tactical Air Command Squadron						TACC
MASS Marine Air Support Squadron		DASC	DASC		DASC	DASC
MACS Marine Air Control Squadron	TAOC ATC	ATC	TAOC ATC	ATC	TAOC ATC	TAOC ATC
LAAD Low Altitude Air Defense	X	Support			Support	X
MWCS Marine Wing Communications Squadron						Communications
MWSG Marine Wing Support Group	Support	Support	Support	Support	Support	Support
MAG (VF/VA) Fixed-wing Marine Aircraft Group	X	X	X	X	X	Support
MALS (fixed wing) Marine Aviation Logistics Squadron	Support	Support	Support	Support	Support	Support
VMGR Marine Aerial Refueler Transport Squadron	Support	X	Support	Support	Support	DASC(A)
VMU Marine Unmanned Aerial Vehicle Squadron	Support	Support	Support	Support	X	Support
VMFA Marine Fighter/ Attack Squadron	X	Escort	X	Support	X	Support
VMA Marine Attack Squadron	X	Escort	X	Support	X	Support
MAG (VH) Rotary-wing Marine Aircraft Group	X	X	X	Support	X	Support

Type of Aviation Unit	AAW	Assault Support	OAS	EW	Air Reconnaissance	Control of Aircraft and Missiles
VMM Marine Medium Tilt-Rotor Squadron	Self-defense	X	Support	Support	Support	Airborne control and coordination
MALS (rotary-wing) Marine Aviation Logistics Squadron	Support	Support	Support	Support	Support	Support
HMH (CH-53E)	Self-defense	X	Support	Support	Support	Airborne control and coordination
HMLA Utility	Self-defense	X	Support	Support	Support	Airborne control and coordination
HMLA Attack	X	X	X	Support	X	Airborne control and coordination

Table 3. Marine Aviation Aircraft Inventory. Adapted from MCDOA (2022).

Squadron Type	Aircraft Type	# of Squadrons (1)	# of Primary Aircraft Authorized
VMFA	F-35B/C	18	10
VMFA	F/A-18C/D	6	5-Jul
VMA	AV-8B	2	14
VMGR	KC-130J	4	15
VMM	MV-22B	14	12
HMLA	AH-1Z; UH-1Y	6	15/12
HMH	CH-53E/K	5.25	16
VMU	MQ-9A	2	Note 2
1 The total number of active squadrons, not including reserve units.			
2 Funding and structure plans are currently being considered to facilitate an additional 3 active VMU squadrons in support of Force Design 2030			
3 Squadron Type identifiers listed in previous table.			

This describes the ACE in its current state. In addition to these squadron types that are assigned to MAWs, there is VMX-1, the OT&E squadron that is described in the next section, and Marine Air Weapons and Tactics Squadron 1 (MAWTS-1), which is under control of Training and Education Command (TECOM).

The *2022 United States Marine Corps Aviation Plan* directed several specified tasks to achieve the DCA's vision for Marine Corps Aviation in 2030 and beyond. One task was to "conduct long-range planning, in excess of a 20-year horizon, to inform service-level development of innovative aviation-related technologies and systems that enhance the MAGTF's lethality and reduce the risk of the future operating environment" (MCDOA, 2022). In the accomplishment of achieving the design of the future ACE, the DCA relies on VMX-1 and MAWTS-1 through additional specified tasks. These are

> For the Commandant, exercise operational control of VMX-1 for flight operations not in direct support of test plans approved by COMOPTEVFOR [Commander, Operational Test and Evaluation Forces] or MCOTEA [Marine Corps Test and Evaluation Activity].
>
> Through TECOM, coordinate with MAWTS-1 to inform aviation warfighting concepts and innovation. (MCDOA, 2022)

With the invention and release of new technology, the specific look of Marine Aviation will undoubtedly shift. The release and transformation of the future ACE will rely heavily on input from T&E.

C. ROLE OF TEST AND EVALUATION

The innovative and industrial arm of the United States has enabled the military to have the best technology and be better equipped than any other military in the world. This is a deliberate decision, with the United States continually outspending other nations in the annual defense budget to maintain the comparative advantage. T&E sits at the crossroads of government and industry. In the past, the government sector led the commercial sector in development, but the current pace of technology has shifted this balance significantly in favor of the commercial sector in recent years. T&E receives new systems at the speed of industry, but test organizations must test the systems through the existing government infrastructure. "The fundamental purpose of T&E is to enable the DOD to acquire systems that support the warfighter in accomplishing their mission" (Office of the Under Secretary of Defense for Research and Engineering [OUSD(R&E)] & Office of the Director, Operational Test and Evaluation [DOTE], 2020, p. 7). However, new systems are not the only way that warfighters can succeed on the battlefield.

Changes to the doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTmLPF-P) shape the future force without creating an initial capabilities document (Chairman of the Joint Chiefs of Staff, 2018). Before investing in further development, test, and evaluation, examining the underlying processes may result in driving the change that will enable the force to be successful. For the Marine Corps, the biggest shift to the DOTmLPF-P came after the release of *Force Design 2030*. The commandant outlined changes to nearly every area, with the biggest shifts in divesting of specific capabilities, battalions, and squadrons to align with matching the rising threat of China. *Force Design 2030* also directed developing capabilities to enable the future force. The Defense Acquisition System integrates with the OT&E agencies in the Marine Corps through two different organizations. These organizations are the MCOTEA for ground systems and COMOPTEVFOR for aviation systems.

1. MCOTEA

The mission of MCOTEA is to "provide OT&E for the Marine Corps and conduct additional T&E as required to support the Marine Corps mission to man, train, equip, and sustain a force in readiness" (U.S. Marine Corps, n.d.b). It is the operational test arm for the Marine Corps Systems Command, which serves as the Department of the Navy's systems command for "Marine Corps ground weapon and information technology system programs in order to equip and sustain Marine forces with full-spectrum current and future expeditionary and crisis-response capabilities" (Defense Acquisition University, n.d.) Operational testing for Marine Corps and Naval Aviation is under the direction of COMOPTEVFOR.

2. OPTEVFOR

Similar to MCOTEA, the mission of Operational Test and Evaluation Forces (OPTEVFOR) is to ensure Naval Forces can "fight and win by evaluating warfare capabilities in realistic combat environments with Fleet warfighters" (Operational Test and Evaluation Force [OTE], n.d.a) It is the Operational Test arm of Naval Air Systems Command (NAVAIR). NAVAIR has an extensive mission, which is to "provide full life-cycle support of Naval Aviation aircraft, weapons, and systems operated by Sailors and

Marines." This support includes "research, design, development, and systems engineering; acquisition; T&E; training facilities and equipment; repair and modification; and in-service engineering and logistics support" (Naval Air Systems Command, n.d.).

The systems under test (SUT) for the Marine Corps have two separate overseeing agencies, depending on if the system is primarily an air or ground system. VMX-1, the Marine OT&E squadron, supports OT on mostly NAVAIR systems, but the squadron supports testing with aviation assets to ensure Marine Corps ground systems seamlessly mesh. Other innovative organizations within the Marine Corps rely on aviation assets or OT experience provided by VMX-1, which include the Marine Corps Warfighting Lab (MCWL) and the Cunningham Group.

3. Other Warfighting Organizations

The Cunningham Group, named after the first aviator in the Marine Corps, Alfred A. Cunningham, is tasked with developing a capability-focused, threat-informed vision for how Marine Aviation operates as a foundational element of the stand-in force in 2030 and beyond (MCDOA, 2022). The Cunningham Group links to the Combat Development and Integration Command and participates in studies and wargames across the DOD, and they partner with industry, academia, and research agencies to align Marine Aviation with emerging concepts. The group is organized into separate divisions focusing on aviation future capabilities, aviation strategy and wargaming, and aviation operational readiness.

The Cunningham Group partners with the MCWL, based in Quantico, VA. The mission of MCWL is to "generate and examine threat-informed, operating concepts and capabilities and provide analytically supported recommendations to inform subsequent force design and development activities" (U.S. Marine Corps, n.d.a). MCWL is organized into four divisions—Wargaming, Science and Technology, Experiment, and the Marine Corps Rapid Capabilities Office.

Both of these organizations focus on science and technology to shape the future force, and they are primarily outside-the-box think tanks for Marines. MCWL and the Cunningham Group do not have assets assigned to them, but they observe Marines in military exercises to inform and assess emerging capabilities and concepts. For aviation,

these organizations sponsor experiments that VMX-1 incorporates into the squadron's long-range test plan.

4. Navy Developmental Test Squadrons

The acquisitions process fields new equipment initially through developmental test (DT), with close integration with contractors. For Marine Corps aircraft, the DT squadrons are located primarily on Naval Air Station Patuxent River, MD. For MV-22, UH-1Y, AH-1Z, and CH-53K, HX-21 is the DT partner. Unmanned aerial vehicle DT testing works with UX-24, and the F-35B DT objectives are driven through a collaborative effort of the F-35 Joint Program Office (JPO). The JPO is the Air Force, Marine Corps, Navy, and foreign military program offices for the F-35 A, B, and C variants.

Depending on the test plan, typical testing on emerging equipment commences with DT and then proceeds to OT and benefits from early involvement in OT. There are several types of test plans designed to maximize limited T&E resources, and one common method is for the test plan to directly integrate DT and OT to reduce testing time and speed products to the fleet (Rendon et al., 2019). The personnel involved in OT and DT work together throughout the life cycle of emerging projects, and this close integration levies the technical perspective of industry, developmental testers, and contractors, with the fleet-representative OT personnel that are tasked with determining operational suitability and effectiveness.

5. Unique Marine Corps Aviation Squadrons

VMX-1 belongs to the unique aviation squadrons within the Marine Corps. VMX-1 and HMX-1 are the two squadrons under control of the DCA. HMX-1, originally formed in 1947 as Marine Helicopter Experimental Squadron One, is now titled Marine Helicopter Squadron One, and is under the administrative control of the DCA and is tasked with presidential support duties (Whittle, 2010). Before the assignment of VMX-22 or VMX-1 as the dedicated operational test squadron, HMX-1 was the operational test squadron for the Marine Corps. The squadron does still conduct OT on the presidential support helicopter, the VH-92A.

Another unique squadron is MAWTS-1, which like VMX-1 is located on Marine Corps Air Station (MCAS) Yuma, AZ. MAWTS-1 is under the direction of the commanding general of TECOM, and their primary role is to conduct two 10-week weapons and tactics training programs each year to train the weapons and tactics instructor (WTI) cadre for all aviation units. The WTI is the highest instructor qualification and can be held not only by pilots or aircrew, but by many other billets involved in Marine Aviation, like intelligence, weather, or maintenance. The *2022 United States Marine Corps Aviation Plan* also directs MAWTS-1 to inform aviation warfighting concepts and innovation.

D. ROLE OF VMX-1

The guidon for the Marine operational test squadron initially read "VMX-22" when the Marine Corps designated the squadron to conduct the testing on the MV-22 in 2003 (Whittle, 2010). VMX-22 was located at MCAS New River, NC, until 2015. In 2015, the squadron headquarters relocated to MCAS Yuma, AZ, changed the designation from VMX-22 to VMX-1, and received detachments of CH-53, F-35B, AH-1, and UH-1 aircraft with the mission of OT. The CH-53 detachment remained at New River, NC, with the intent of receiving the CH-53K, and the F-35B detachment was located at Edwards Air Force Base (AFB), CA. In 2019, the F-35B detachment moved to Yuma, AZ. The number of CH-53K aircraft was reduced from four to two for the New River detachment after the aircraft became initial operations capable (IOC) and CH-53K aircraft were transferred to the first CH-53K squadron. Table 4 shows the current allocation and location of VMX-1 aircraft.

Table 4. VMX-1 Aircraft Inventory

Aircraft Type	**Quantity**	**Location**
AH-1Z	3	MCAS Yuma, AZ
CH-53K	2	MCAS New River, NC (1)
F-35B	6	MCAS Yuma, AZ
MQ-9A	Note 2	Note 2
MV-22B	5	MCAS Yuma, AZ
UH-1Y	3	MCAS Yuma, AZ
1 CH-53K relocation to MCAS Yuma, AZ scheduled to occur in FY24		
2 Squadron allocated to receive 2 MQ-9A aircraft in FY 25		

The mission statement for VMX-1 is to

> conduct operational test and evaluation of all U.S. Marine Corps aviation platforms and systems under the authority of Commander, Operational Test and Evaluation Force and Director, Marine Corps Operational Test and Evaluation Activity. Create, document, and disseminate initial tactics, techniques, and procedures for Marine aviation platforms and systems. Support further concept development and refinement of Marine aviation tactics, techniques, and procedures. Coordinate and conduct government-sponsored experimentation and tactical demonstrations. Provide operational support as directed by Deputy Commandant for Aviation. (Marine Operational Test and Evaluation Squadron 1, 2018, p. 2)

This mission charges the squadron with OT and ties the squadron to conducting tasks from Marine Corps Systems Command and MCOTEA, NAVAIR and OPTEVFOR, and MCWL and the Cunningham Group. Additionally, F-35s participate in Joint OT&E under the U.S. Operational Test Team (UOTT). The squadron mission also directs the implied tasks of maintaining pilot and aircrew proficiency to develop tactics, techniques, and procedures.

In the accomplishment of this mission, VMX-1 is organized into a headquarters with functional areas that match comparable units, like administration, logistics, and operations. Additionally, it has unique departments dedicated to components of the mission, including an Assault Support Department for Operational Test; Assault Support Maintenance; Tactical Air (TACAIR) Department for Operational Test; TACAIR Maintenance; a Tactics and Integration (T&I) Department with a Fires Division, Science and Technology Division and Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, Reconnaissance, and Targeting (C5ISRT) Division; and the CH-53K detachment in New River.

E. CHAPTER SUMMARY

OT&E for Marine Aviation is aligned to fit within the institutional structure of the Marine Corps and those outlined by DOD directives. The mission of VMX-1 fits within the larger goals outlined in the *2022 United States Marine Corps Aviation Plan.* VMX-1 is fleet representative, with personnel with wide backgrounds coming from units across the spectrum of the ACE. The following chapter will review literature on determining the right

manpower breakdown for OT&E and issues with cost and schedule delays for higher acquisition category (ACAT) programs.

III. LITERATURE REVIEW

Improving OT&E is an incredibly broad topic, and most literature on the subject focuses on the significance of OT&E rather than the improvements process to speed acquisitions. Delays in OT&E are not unique to Marine Aviation, and reviewed literature shows similar root causes of manpower training shortfalls and technical issues during development. Workforce development continues to be an initiative from leadership at all levels, as described in the government directives and a journal article. There are also numerous government reports discussing issues in T&E that increase risks to programs and cost.

A. GOVERNMENT PUBLICATIONS

> The fundamental purpose of T&E is to enable the DOD to acquire systems that support the warfighter in accomplishing their mission. To that end, T&E provides engineers and decision-makers with knowledge to assist in managing risks; to measure technical progress; and to characterize operational effectiveness, operational suitability, interoperability, survivability (including cybersecurity), and lethality. This is done by planning and executing a robust and rigorous T&E program. (DOD, 2020, p. 7)

This purpose is placed within the AAF, and the DOD instruction directs the program manager to "develop an acquisition strategy for MDA (Major Defense Acquisition) approval that matches the acquisition pathway processes, reviews, documents, and metrics to the character and risk of the capability being acquired" (DOD, 2020, p. 19). A customizable framework allows for creativity in the acquisitions process. Despite the AAF guidance, the 2022 National Defense Strategy stated,

> Our current system is too slow and too focused on acquiring systems not designed to address the most critical challenges we now face. … We will better align requirements, resourcing, and acquisition, and undertake a campaign of learning to identify the most promising concepts, incorporating emerging technologies in the commercial and military sectors for solving our key operational challenges. (DOD, 2022, p. 19)

From the perspective of the Marine Corps, General Berger's guidance was encapsulated in *Force Design 2030*. Expanding on this directive, the Commandant released

Training and Education 2030. The focus of this publication is on the warfighters that will employ the emerging technology in the future fight, but it does not discuss acquisition process improvements or developing the acquisition workforce.

> Progress in the initial phases of the Force Design 2030 modernization effort has enabled some warfighting areas to transition from force design to force development. As a result, we must increasingly focus and dedicate the necessary effort and resources to train and educate the force that will man, operate, and sustain those new units and capabilities. As has always been the case, the individual Marines operating the new systems are the true source of our relative advantage—not the systems themselves. The foundation of our Corps is and has always been the individual Marines that fill its ranks. Continuously modernizing and adapting T&E [Training and Education] to account for technological advancements and emerging concepts, as well as societal changes with how individuals best receive and process information, will ensure continued warfighting success long into the future. (Berger, 2023, p. 2)

B. JOURNAL ARTICLE

A 2020 article titled "With the New Breed: Transforming the 8059 Aviation Acquisition Officer Corps to Best Support Force Design 2030," outlined initiatives to develop the workforce within Marine Aviation. In the article, Lieutenant Colonels Zarra and Ramthun (2020) described three initiatives to develop a more experienced Aviation Acquisition Officer:

1. **"Formalize a framework."** Create multiple entry points for both junior grade pilots and other aviation-related MOS personnel to enter the acquisition force.
2. **"Right-size the population**." Increase the aviation acquisition force structure to increase the size of the depth joint service and professional military education assignment requirements.
3. **"Sharpen the saw."** Increase career development opportunities to professionally develop the 8059 cadre.

The article states, "75 percent of all 8059 MOS accessions originate from the test and evaluation field because of the opportunity to accrue acquisition career time while serving as test aircrew" (Zarra & Ramthun, 2020, p. 49). VMX-1 is the first exposure for

many Marines to the acquisitions field, and the secondary MOS of Aviation Acquisitions Candidate (8057) provides experience for future opportunities in the acquisitions field. However, much of the training for OTDs is learned on the job, and this article stated that opportunities need to be increased throughout the fleet to develop greater experience and emphasis on acquisition.

C. PREVIOUS NAVAL POSTGRADUATE SCHOOL THESES

A Naval Postgraduate School thesis from 2009 discussed the education of the T&E workforce. In it, the author described the disparity between the 3-day training for OTDs and the 48-week test pilot school (TPS) course for DT pilots. He stated,

> The inadequate training of OTDs often forces them to rely on their DT counterparts or development contractors for support in planning and analysis of OT&E. While this can be helpful, the DT testers and development contractors have different objectives and their views are sometime in conflict with OT&E policies. OT&E, by law and policy, must be performed independently from and uninfluenced by development organizations. (Barrett, 2009, p. 44)

The 3-day OTD course is still required training for OTDs within OPTEVFOR, but there are additional courses OTDs can attend, as availability and work schedule allow, that focus on specific aspects of OT&E. For OTDs from VMX-1, attendance at OPTEVFOR courses requires travel from Arizona to Virginia and must be scheduled around existing OT events.

More recently, a 2022 thesis from Lieutenant Commander Duran at the Navy's Fixed Wing OT Squadron focused on having fleet squadrons conduct OT. While the results showed the consequences to cost, schedule, and performance to be more beneficial for keeping OT with OT squadrons, his observations on training of OTDs were also useful for pilots at VMX-1:

> An OTD must navigate the political demands of accountability, funding, and scrutiny associated with their projects as a full-time duty. Additionally, the technical knowledge of tests and assessing the validated requirements of a system from end to end necessitates specialized training. (Duran, 2022, p. 70)

Training is integral for the success of OTDs, because much of what they learn is through introductory courses or learned on the job. In the era of increasingly complex acquisition programs, the role of the OTD continues to be vital. The next section discusses government reports and how schedule delays affect the fielding of emerging technology.

D. GOVERNMENT REPORTS

In past years, there have been numerous Government Accountability Office (GAO) reports discussing delays or cost overruns with aviation acquisition programs. Of surveyed reports, VMX-1 conducts tests on both the CH-53K and the F-35B. A GAO report from March 2021 focused on the cost and schedule risks for the CH-53K. While the program went on to achieve IOC in April 2022 and is on track to meet the operational deployment timeline, the concerns were valid throughout initial operational test and evaluation (IOT&E; Eckstein, 2022). The report showed that, despite the delays, the Marine Corps still fully intended to continue to field the aircraft for deployment.

> Subsequently, technical challenges discovered during developmental testing caused additional delays. As a result, the program now plans to deliver initial capability to the warfighter in September 2021, 6 years later than originally planned. However, according to the latest program schedule, delivery of the initial capability will be a year before the helicopters have been fully tested and proven in an operational environment. We have previously reported that declaring initial operational capability in advance of testing increases the risk of cost growth and schedule delays. According to Marine Corps officials, they plan to declare initial operational capability with the four SDTA [system demonstration test articles] helicopters. They further stated that even though some performance requirements will not be tested before declaring initial operational capability, this does not mean that the helicopter is not capable of meeting those performance requirements. In addition, they stated that there is time to test these capabilities prior to deployment. The program is scheduled to achieve first operational deployment in 2024, and be fully operationally capable in 2029. According to program officials, operational deployment is when the Marine Corps will use the helicopter in overseas missions. (GAO, 2021, p. 19–20)

Across all services, there are numerous GAO reports on the F-35. A GAO report from April 2022 discussed delays in developing the F-35 Joint Simulated Environment, a simulated environment for conducting scenarios with a complex enemy structure, and the potential for risk of schedule delay if problems continued.

> We found that F-35 simulator delays continue to prevent DOD from completing initial operational test and evaluation and the program office has postponed the full-rate production decision—the final development milestone. The duration of this delay is not clear; however, the program is years behind schedule in completing development while continuing to acquire up to 152 aircraft per year. The more aircraft produced before operational testing is complete, the higher the risk of increased costs to retrofit those aircraft if issues are discovered. While the F-35 program modified its delivery schedule to accommodate supply chain challenges and delays due to the COVID-19 pandemic, contractors continue to deliver airframes and engines late and with quality issues. (GAO, 2022, p. 14)

The Director of Operational Test and Evaluation's (DOT&E) annual report from FY2022 summarized issue with the F-35 as follows: "The F-35 program continues to field immature, deficient, and insufficiently tested Block 4 mission systems software to fielded units. The OT teams continue to identify deficiencies that require software corrections and, with them, additional time and resources" (Director, Operational Test & Evaluation [DOT&E], 2023, p. 41). The Marine Corps declared the F-35B full operational capable (FOC) with VMFA-242 in May 2022 (Rusavskiy, 2022).

E. CHAPTER SUMMARY

Increasing the pace at which capabilities are fielded to the fleet is dependent on having an adequately trained workforce within the OT community and receiving a viable product from DT. While the AAF creates abbreviated pathways for new technology, its technology readiness levels (TRLs) must correspond correctly to prevent the system from reaching OT&E prematurely. OTDs should become involved in systems in development early and throughout testing, but limited manpower means personnel must be carefully invested into programs to avoid lengthy involvement and an inability to complete other assignments. The next chapter examines resource constraints inside VMX-1 and compares systems under test in OT to improve the scheduling and reporting process for OT&E.

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IV. ANALYSIS

To this point, this capstone applied project focused on the role and function of VMX-1 in acquisition and OT and literature review focusing training professionals within the acquisition force and immature technology. This chapter will examine the shortfalls and resource constraints facing the squadron and the typical products and discuss the process flow for projects conducted by VMX-1. It will then review timelines of past projects to highlight important milestones while conducting test planning, execution, and reporting.

A. RESOURCE CONSTRAINTS FOR VMX-1

Many of the resource challenges that VMX-1 faces are similar to those faced by other aviation units within the Marine Corps. VMX-1 is unique in that specialization training is required for operational test directors (OTDs) and the squadron possesses fewer assets to train personnel. The root causes of delays to test reporting for OT&E are analyzed in the fishbone diagram in Figure 3. The following sections will describe each of the resource constraints in the diagram.

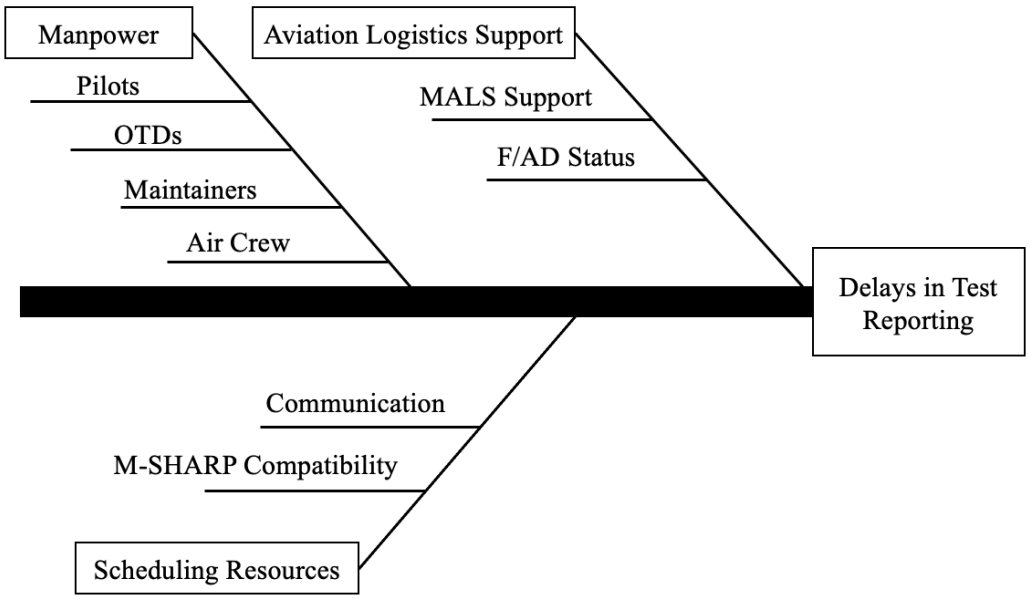

Figure 3. Root Cause Analysis for Delays to OT&E Report Generation for VMX-1

1. Issues with Manpower

The personnel assigned to VMX-1 consist of officers, enlisted Marines, contractors, and civilians. Marine Corps manning is directed by published tables of organization (T/O). The T/O for VMX-1 was signed in 2018, but there is an approved table of organization and equipment change request (TOECR) for VMX-1 to receive additional manpower in Fiscal Year (FY) 2023. Personnel assignments are under the guidance of the Manpower and Reserve Affairs branch in Headquarters Marine Corps. Manning is the "portion of the unit's T/O that, within budgetary constraints, is authorized to be filled with Marines" (Commandant of the Marine Corps [CMC], 2012, p. 3). Staffing is the portion of manning that can be "filled with assignable inventory in accordance with the priorities established by the commandant" (p. 3). The staffing goal for the Marine Corps is 90 percent (CMC, 2012).

The *Marine Corps Personnel Assignment Policy* directs permanent assignment of Marines to units and duty stations. This policy was updated following the commandant's

release of *Talent Management 2030*, which was a directive to gain and maintain individuals with the desired skills sets to achieve the *Force Design 2030* initiative. The order establishes time on station (TOS) requirements "to stabilize the movement of Marines and their family members, and to reduce permanent change of station costs" (CMC, 2021, p. 1-1). Directed TOS for Marines moving within the continental United States is 36 months. The updated order included aviation-related qualifications and designations to assignment criteria consideration for the transfer of aircrew and maintainers. Shortfalls for aviation aircrew and maintainers exist throughout the Marine Corps, and VMX-1 is not immune to these challenges.

Manpower is a multifaceted issue that drives the largest of VMX-1's resource constraints. A thorough look at the types of personnel assigned to the squadron explains the challenges associated with leveraging the desired skillset to achieve the assigned mission. The following sections discuss pilots, OTDs, maintainers, and aircrew. OTDs are pilots, and aircrew are maintainers; however, OTDs and aircrew present additional challenges within the previously listed categories.

a. Pilots

VMX-1's mission to create, document, disseminate, and refine tactics, techniques, and procedures drives a requirement for all the squadron's pilots to be fleet representative and in at least their second flying tour. This means the training pipeline for VMX-1 pilots is completion of the initial flight qualifications, completion of the fleet replenishment squadron, service in a fleet squadron for at least four years, and then assignment to VMX-1. The common analogy with pilot training is it is a faucet, and there are either too many pilots being trained or there are too few. This issue is even further exacerbated when trying to forecast pilots required for second tour flying assignments.

The military is experiencing a pilot shortage, and the Marine Corps has joined the sister Services in offering a monetary bonus to retain necessary pilots (Parrish, 2017). The current fleet inventories for pilots are indicated in Table 5. Additional pilots are needed in the fixed wing (FW) and unmanned aerial system (UAS) populations, and they appear to be stable in the rotary-wing / tiltrotor (RW/TR) populations. However, these numbers do

not account for the qualifications of pilots within those military occupational specialties (MOSs), which leads to challenges filling billets for deploying squadrons that need to train their junior pilots before an upcoming deployment. Experienced pilots are also required in squadrons like MAWTS-1, HMX-1, and VMX-1, and in roles throughout the Marine Corps, like forward air controller or staff advisor.

Table 5. Aviation Officer Health. Source: MCDOA (2022).

Aviation Officer Health (Mar 2022)						
MOS	Active			Reserve		
	GAR	On-Board	%	GAR	On-Board	%
7509 (AV-8)	185	156	84%	23	21	91%
7518 (F-35)	498	197	40%	5	12	240%
7523 (F/A-18)	326	234	72%	71	57	80%
7556/57 (KC-130)	377	324	86%	97	57	59%
F/W Pilot Total	**1386**	**911**	**66%**	**196**	**147**	**75%**
7532 (MV-22)	986	850	86%	84	68	81%
7563 (UH-1)	369	389	105%	71	43	61%
7565 (AH-1)	503	541	108%	101	76	75%
7566 (CH-53)	616	558	91%	39	51	131%
R/W & TR Pilot Total	**2474**	**2338**	**95%**	**295**	**238**	**81%**
7315 (RQ-21)	154	125	81%	3	5	167%
7318 (MQ-9)	63	38	60%			
UAS Pilot Total	**217**	**163**	**75%**	**3**	**5**	**167%**
7525 (NFO)	68	119	175%	11	6	55%
6002 (Aircraft Maintenance)	254	303	119%	17	24	141%
6602 (Aviation Supply)	216	248	115%	19	22	116%
7202 (Air Command and Control)	197	203	103%	8	30	375%
7204 (LAAD)	69	75	109%	3	1	33%
7208 (Air Support)	162	191	118%	28	34	121%
7210 (Air Defense Control)	122	116	95%	13	13	100%
7220 (Air Traffic Control)	93	83	89%	6	5	83%

Note. GAR = Grade Adjusted Recapitulation Report

VMX-1 requires experienced pilots as well. The current pilot population by MOS is listed in Table 6 with the allocated number of pilots in the T/O, the current number of pilots, and the approved number of pilots in the TOECR. The current on hand number of pilots does not account for pilots that are not available to fly due to a medical or other condition, so in populations like H-1, CH-53, or UAS, if the pilots are "med down," there may not be personnel available to pilot the aircraft. Additionally, VMX-1 is only one pilot short of the current T/O for UH-1 pilot, but two pilots are required for the tactical employment of the aircraft. The training and readiness (T&R) manual for each T/M/S aircraft specifies the crew configuration for events. While there are flights where an AH-1 or UH-1 may be flown single-piloted, any flight outside of a day familiarization flight requires two trained pilots. This is the case with the MV-22 or CH-53, because those aircraft are considered multi-piloted, meaning the crew in both pilot seats operating the aircraft must be qualified to fly it.

Table 6. VMX-1 Pilot Quantities and Projected Quantities

Pilot	MOS	Current T/O	Current O/H	TOECR	Multi-piloted	Aircraft
AH-1	7565	3	3	5	N	3
UH-1	7563	2	1	5	N	3
MV-22	7532	12	10	13	Y	5
F-35	7518	11	8	13	N	6
UAS	7315	5	3	7	N (2)	TBD
CH-53	7511	5	5	3	Y	2 (3)
1. T/O allocates for one additional pilot with 8042 MOS- Colonel, Naval Aviator/Naval Flight Officer/Unmanned Aircraft System Officer; current VMX-1 Commander also holds MOS of 7518						
2. UAS crew consists of enlisted operators						
3. CH-53K aircraft transferred to HMH-462 in FY 23						

If the squadron were to fly all the AH-1 or UH-1 aircraft, the squadron would not have enough pilots. In those cases where VMX-1 pilots cannot fly or all aircraft are scheduled, the squadron requests pilots from fleet units to augment and fly with VMX-1 pilots. Furthermore, there are no H-1 squadrons assigned to MCAS Yuma, so VMX-1 must

request pilots to travel or coordinate for additional pilots while fleet squadrons are away from their home stations on cross-country flights or on detachments.

Another consideration is that second-tour pilots are often approaching the end of their aviation commitment. While the assignments manual requires 36 months TOS, the requirement for separation is 24 months if coming from a continental United States (CONUS) unit or 12 months if coming from outside CONUS. This reduces the tenure of pilots in the squadron because replacement pilots cannot be assigned until officers have an approved separation date. It also affects personnel available to conduct OT, because when the pilot separates, the replacement pilots will need to receive OT training to participate in the unique mission of the squadron.

To remain fleet representative, pilots at VMX-1 must fly to remain proficient in mission skills. The T&R program manual "provides aviation communities with the requisite standards and regulations regarding the training of aircrew, aviation ground communities, and UAS personnel" (CMC, 2020, p. 1-3). The manual categories aviation training communities into four groups: "tactical manned flight communities"; "unmanned aerial systems"; "operational support aircraft, adversary support, and executive transport"; and "tactical aviation ground communities" (CMC, 2020, p. 1-8). OT&E is not directly included in this manual, and flights in support of OT must have dedicated risk assessments conducted on the test plan. For training flights to maintain tactical proficiency for aircrew, VMX-1 uses the T&R manuals as the baseline and briefs any by-exception risk factors to the commanding officer. In preparation for test events or to maintain tactical proficiency, the squadron may schedule fewer flight hours to achieve the desired level of currency based on the pilots' previous flight experience, but there is no minimum qualification baseline for VMX-1 pilots to reduce flying risk.

The VMX-1 T/O has a few billets that specify the requirement for a pilot to be a WTI, but most pilots do not require additional flight qualifications to be assigned to the squadron. HMX-1 solicits pilots annually via a Marine administrative (MARADMIN) message with the established baseline of night systems instructor (NSI). The NSI qualification is the first MAWTS-1 instructor-evaluated syllabus to ensure standardization across squadrons. By establishing the baseline qualification of NSI, HMX-1 is able to

mitigate risk by ensuring a previously evaluated level of ability for applying pilots. VMX-1 does not release an annual MARADMIN to recruit personnel, and pilot "hot fill" requests have been sent out by assignment monitor officers during the previous permanent change of station cycles. Pilots at VMX-1 can continue to fly and receive duty involving flying-operational orders and rate flight pay in a non-deploying status. VMX-1 recently implemented an application process when pilots express interest in coming to the squadron to select the most qualified applicants, but the available pool is limited because of manpower constraints.

The requirement for VMX-1 pilots to be fleet representative means there should be varying levels of pilot qualifications and designations within the squadron as long as they meet the qualifications to safely conduct the test. During OT, fleet representative pilots are able to collect data and experience common issues that fleet pilots and aircrew expect to see. While outside pilots and aircrew can be requested from fleet squadrons, being able to source all needed personnel from within VMX-1 would reduce the coordination required from VMX-1 OTDs before the start of a test. The OTD is the key player to accomplish the squadron objectives of OT.

b. Operational Test Directors

The OT&E manual defines the role of OTD as

> a qualification that ensures the individual is capable of providing military leadership, fleet experience, and tactical acumen to OT&E, specifically regarding the direction of operational test execution. The OTD is assigned to one or more programs. The OTD is responsible for overseeing tactically realistic detailed test planning, thorough test execution, to include detailed data collection, and that the observed results are accurately documented in the Test Report. In addition to ensuring that the requisite phase of test execution is conducted properly, the OTD leads the test team in ensuring associated documentation is "Flag-signature ready" and in compliance with current policies and procedures. (OTE, 2021a, p. 2-12)

The OTD drives the tempo for VMX-1. They coordinate with outside entities to schedule ranges and confirm outside support. They work with the operations department to ensure aircrew are scheduled and proficient for events, and they communicate with the maintenance department to ensure the aircraft is properly configured for testing. When test

schedules slide, the OTDs often must go back to the long-range calendar and reshuffle other test events to ensure the squadron is still able to accomplish OT.

Of the pilot MOSs on the VMX-1 T/O, nearly all hold the billet identification code (BIC) of OTD. However, T/O does not have BICs for the other necessary billets required for the squadron to function. Only a few pilots are assigned into the OTD billets, and the rest serve in billets identical to a fleet aviation squadron, like operations, safety, or maintenance. Therefore, nearly all the pilots assigned to the squadron hold the BIC of OTD but are not in fact an OTD. The squadron currently has at least one dedicated OTD per T/M/S, and they work in the CH-53K, ASD, or TACAIR projects departments.

The T/O also provides the additional MOS of 8057 to squadron OTDs. 8057 is the Marine Acquisition Officer Candidate, and officers in 8057 billets are required to meet the professional educational standards set by the Department of the Navy Defense Acquisition Workforce Improvement Act operating guide (CMC, 2022). The prerequisites for an 8057-designated officer are Practitioner Level certification (formerly Level II) in a primary acquisition career field, which directs required years of experience. The second-tour pilot population from fleet squadrons does not have experience in acquisition related fields, and assignment to VMX-1 is their first exposure to OT&E. Therefore, they receive all their training for OT through formal education and on-the-job training.

DT pilots graduate from the U.S. Navy (USN) Test Pilot School for helicopter and tiltrotor aviators and U.S. Air Force (USAF) Test Pilot School for fixed wing aviators. The USN and USAF Test Pilot Schools are 48-week courses that teach DT pilots in the full spectrum of T&E for aircraft and aircraft systems. OT pilots, in comparison, do not receive this level of formal schooling. OTDs attend an OTD course in Norfolk, VA, which is a 3-day course on the "high-level overview of OPTEVFOR and DOD policies and methods" (OTE, n.d.b). The objective of the OTD course is "to provide new testers and support personnel with baseline knowledge of weapon system acquisition, and introduce them to policies, procedures, documentation and reports required by DOD and SECNAV in conducting OT&E" (OTE, n.d.b). OPTEVFOR offers additional courses to OTDs on topics like test planning and blue gold sheet writing, but there is a large disparity between the level of instruction for DT pilots and OTDs.

The level of on-the-job training and experience gained from working different projects drives the need for OTDs to maintain tenure in their billet to manage enduring projects. Test events inevitably slide, and this occurs within the transient timelines for active duty personnel. Oftentimes the OTD that planned the test event is no longer in the squadron when the test is final, and all the notes and lessons learned during the test process are passed down throughout the different phases. Orders to VMX-1 last three years, but the squadron does not have a directive that an OTD shall stay in the billet for their entire duration of the assignment. Tenure for OTDs leads to more thorough understanding of the job. This is where the structure of VMX-1 differs from that of a fleet squadron, because civilian and contractor support supplements this turnover shortfall and slowdown resulting from training personnel.

Prior to the recent approval of the TOECR, the squadron did not have an allocation for an 8059, Marine Acquisition Officer–Aviation. To receive this specialized MOS, this individual must be in an aviation MOS and have 36 months' experience in acquisitions. The T/O change allocated one 8059 to fill the role of chief operational test director, and the billet is designed to oversee all OT projects assigned to VMX. The emphasis on filling the role with an experienced individual enhanced the ability of the squadron to conduct its mission. Turnover and lack of experience is also mitigated with contractor and civilian support, but OT does not have the same level of contractor support as DT. The unique mission of VMX-1 presents a different set of challenges to the composition of personnel within the squadron and the structure of the Marine Corps. These issues are amplified when examining manpower for maintainers as they prepare and repair aircraft for flight proficiency and test events.

c. Maintainers

When examining manpower resources, it is easy to focus on pilot shortages, but maintainer manning presents a significant concern as well. There is no guidance that maintainers need to be in a fleet squadron before arriving to VMX-1. Unlike most fleet squadrons, where the maintenance department is structured to repair one type of aircraft, the VMX-1 maintenance department is organized to repair all types of Marine Corps

aircraft. The squadron is currently set up in three different hangars with CH-53K in New River, NC; F-35B in their own hangar in Yuma, AZ; and MV-22B, UH-1Y, and AH-1Z sharing a hangar in Yuma, AZ. Staffing is aligned to repair the number of aircraft possessed by the unit, so a squadron like VMX-1 will have fewer maintainers because of the lower number of aircraft for each T/M/S. The RW/TR hangar has a maintenance contract to supplement maintainer support during the day shift, and they are used for aircraft phase maintenance and other specific aircraft repair tasks or administrative duties.

The structure of the Marine Corps aviation organizational level (O-level) maintenance department is organized in the functional areas depicted in Figure 4. Without going into the duties of each division, the roles of maintenance on specific aircraft components are divided and placed under the responsibility of generally one of three work centers: avionics, line, or airframes. The actions are directed by Maintenance Control and verified for safety and standardization by the Quality Assurance (QA) Division.

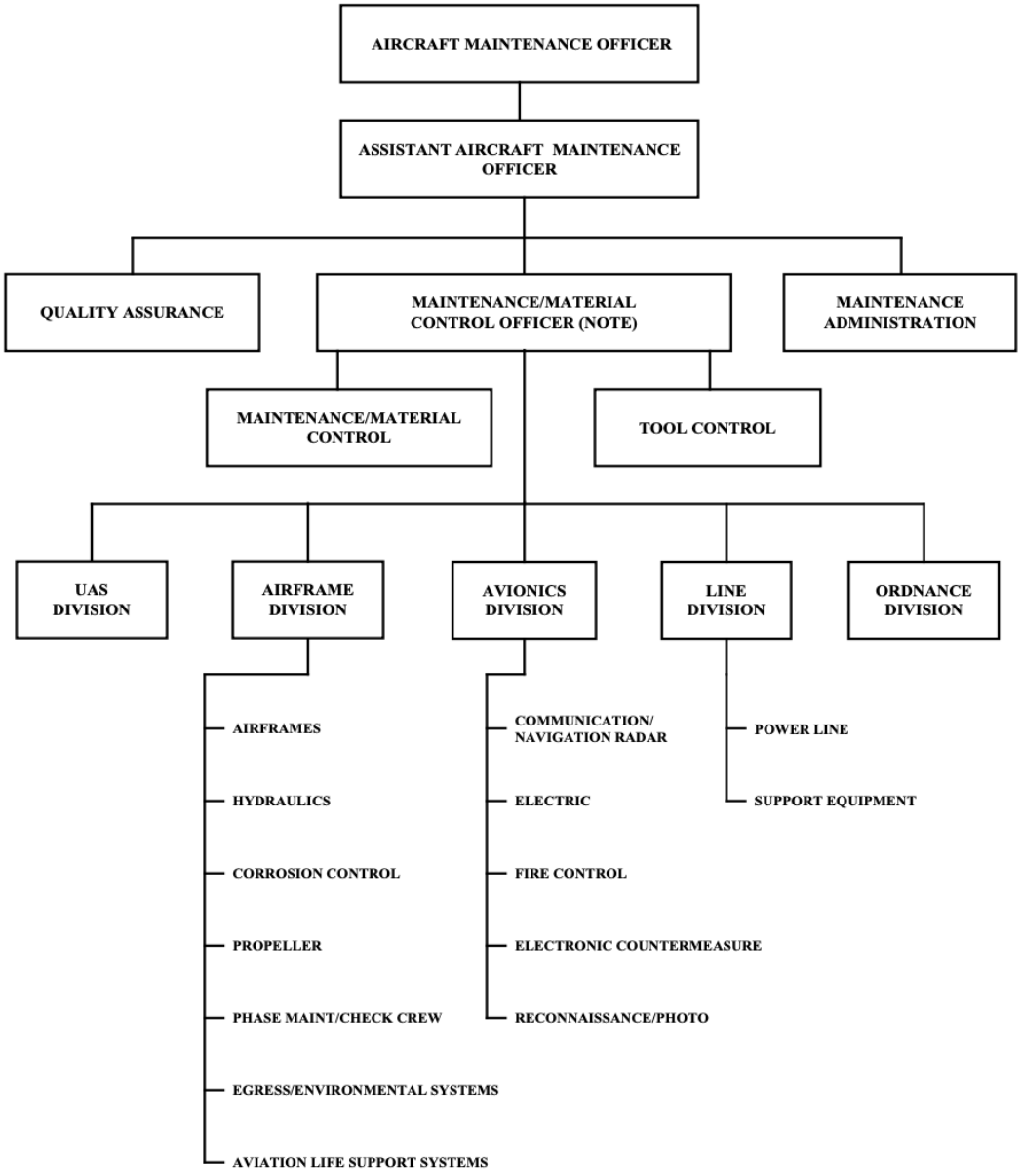

Figure 4. O-Level Maintenance Department Standard Organization. Source: Naval Air Systems Command (2022, p. 3-42).

The QA Division is responsible for ensuring the quality of aircraft, engines, components, and equipment, and it is staffed with quality assurance representatives from the primary three work centers in the squadron. QA is also responsible for maintainers within those divisions with the senior maintenance qualifications of collateral duty quality

assurance representative and collateral duty inspector. Each maintenance qualification has an assigned syllabus and, once complete, the maintainer keeps those qualifications when they transfer to subsequent units with same-type aircraft. Personnel that transfer into VMX-1 bring with them previous maintenance and fleet experience that is useful for OT. First-assignment maintenance Marines join the squadron as a basically qualified worker and need to progress through assigned maintenance qualification syllabi. With fewer aircraft and comparatively fewer flight hours at VMX-1 opposed to fleet squadrons, the amount of maintenance actions to repair aircraft post-flight is reduced. Compared to a fleet squadron maintainer, a junior maintainer at VMX-1 may require more time to complete assigned maintenance syllabi and with fewer repetitions of common maintenance actions. Delays in gaining maintenance qualifications could also have career impacts, because MOS Roadmaps dictate what qualifications Marines should have to be competitive for promotion at each rank. First-assignment Marines are at a disadvantage at VMX-1, but maintenance leadership creatively seeks training opportunities to complete qualifications.

All squadrons encounter challenges with maintenance staffing, and the updated assignments order targets aviation-related qualifications and designations to remedy shortages in qualified individuals across the fleet. VMX-1 currently has sufficient maintenance personnel to have a day shift and a night shift of maintenance for the F-35 hangar, and a single shift for the H-1 and MV-22 hangar. The single shift is conducted during daytime hours to keep a normal home/life schedule. There is sufficient depth in the RW/TR hangar for a swing shift of a few maintainers to accommodate late flights, but there are not enough personnel to conduct maintenance actions at night. Yuma summer heat is extreme and physically demanding, and frequent breaks are required during work hours. With the approved T/O change, additional maintainers are allocated to the squadron to build a night crew to take advantage of work in cooler temperatures and increase maintenance work hours.

The mission of VMX-1 requires unique aircraft configurations for test. OT involves not only tactics, techniques, and procedures (TTP) development and OTD reports, but also maintainer feedback. While the leaders within the maintenance department have been previously assigned to fleet squadrons, many enlisted personnel receive orders away from

flying units to be assigned as recruiters or drill instructors. Many of the staff noncommissioned officers return to VMX-1 after these assignments and must refresh in maintenance practices to reestablish proficiency in their qualifications. This break in exposure to fleet maintenance practices, coupled with the squadron's inclusion of assigned first-term maintainers, limits the squadron's ability to provide valid maintainer feedback for OT.

d. Aircrew

Another issue with first-term assignment of enlisted Marines is the requirement to train fresh MV-22 and UH-1Y crew chiefs. VMX-1 pilots receive their tactical training from their first fleet squadron and require fewer flight hours to maintain flight proficiency. Crew chiefs arriving from the fleet replenishment squadron require training flights to complete their assigned T&R basic syllabus. All personnel are assigned the basic program of instruction (POI) when they begin training in a syllabus (e.g., pilot, crew chief, etc.). Upon demonstration of an individual skill proficiency, the skill transitions to a "maintain" status.

> The requirement to demonstrate skill proficiency more than once is established by the community and is reflected by events in the skill having an assigned proficiency period. Proficiency period is an amount of time (expressed in calendar days) between each demonstration of event proficiency. (CMC, 2020, p. 2-5)

With the definition of the POIs, a squadron can determine how to allocate resources to accomplish the training objectives for aircrew. "The Core Competency Resource Model (CCRM) is a qualitative analytical tool (model) that displays external resources required to attain and maintain training/combat proficiency. This tool objectively captures and displays the required external resources for readiness" (CMC, 2020, p. 1-5). One of the outputs of the CCRM is the Sortie Based Training Program, which generates the flight hours goal for the squadron during the fiscal year.

Fleet squadrons work to accomplish training objectives within their assigned deployment cycles. The squadrons have an assigned mission statement, and all training prepares their aircrew to best complete that mission when needed. The mission of VMX-1

is to complete OT&E with the implied task of maintaining pilot and aircrew proficiency. Previously untrained aircrew require dedicated sorties to complete initial training to establish a baseline level of proficiency. If untrained aircrew are required to participate in tactical flights without proper training, the VMX-1 commanding officer accepts additional risk. For mitigation, initial aircrew training must occur between scheduled test periods, and the squadron must use limited resources or coordination with outside units to accomplish this initial training.

Fleet squadrons, with a higher total number of aircrew, are often able to partner junior aircrew together to complete initial events and conduct training that satisfies the requirements for multiple skills during a single flight. VMX-1 has fewer aircrew and aircraft, so the proportion of assets needed to complete an initial event is significantly higher compared to a fleet squadron. Additionally, with shifting test windows, scheduling ranges and other outside support becomes difficult as a change in schedule results in a complete reshuffling of cards to complete preparation for a test event and training during a specific light level at night, for example. The geographically dispersed location of VMX-1 creates challenges with flying combined flight events with fleet squadrons as well, and aircrew must travel if they are to brief and fly with like-T/M/S squadrons. Ultimately, completing initial training events for junior crew chiefs is crucial, and with limited personnel at VMX-1, having fully trained aircrew generates useful feedback for OT&E. The necessity to train first-assignment crew chiefs places an additional scheduling burden on the OTDs and the operations department at VMX-1.

2. Issues with Aviation Logistics Support

VMX-22, the Osprey Test and Evaluation Squadron, was redesignated to VMX-1 and relocated from MCAS New River to MCAS Yuma in 2015. The redesignation shifted the focus to OT&E on all Marine Aviation platforms and sought to take advantage of both the ranges in the Yuma Range Complex and the partnership with MAWTS-1 for TTP development and aviation development tactics and equipment (ADT&E). As stated earlier, MAWTS-1 conducts two WTI classes annually, and while those courses are occurring, fleet units augment with aircraft, maintainer support, and aviation logistics.

Outside of that, Yuma is predominantly a jet base. Following the decommissioning of the AV-8B, former Harrier squadrons are now activated as F-35B squadrons. Yuma has five active F-35B squadrons under MAG-13 and one UAS squadron, designated as Marine Unmanned Aerial Vehicle Squadron One (VMU-1), on the flight line. Marine Aircraft Logistics Squadron 13, MALS-13, provides the logistics support to these squadrons, as well as aviation logistics to VMX-1.

MALS provides intermediate level (I-level) maintenance support. "The primary focus of I-level maintenance is to produce ready-for-issue parts and ready-for-use support equipment in sufficient quantities to support aircraft operations" (Commander, Naval Air Forces, 2022, p. 3-1). The MALS is tasked organized to provide more specialized maintenance support to organizational level squadrons, and their T/O is designed to match the aircraft in the corresponding MAG. In this case, MALS-13 pairs with MAG-13, and the T/O has I-level MOSs with a focus on fixed wing maintenance support. I-level squadrons have access to the Optimized Organization Maintenance Activity system, which is used to source aircraft parts from the fleet inventory. However, a comparison of MALS-13 to MALS-26 or MALS-39 provides background on how the location of VMX-1 in Yuma places further challenges on the squadron's H-1s and MV-22s.

MALS-26 is located at MCAS New River and is the I-level support for the MV-22 Fleet Replenishment Squadron, VMMT-204, and five MV-22 squadrons under MAG-26. MALS-39 is located at MCAS Pendleton and is the I-level support for the H-1 Fleet Replenishment Squadron, HMLAT-303, two MV-22 squadrons, and four H-1 squadrons under MAG-39. With more squadrons in a single location, there are oftentimes more available parts for tenant squadrons to access to return aircraft to up status. Personnel in those squadrons have assigned H-1 or MV-22 maintenance syllabi or have more experience working with those aircraft when compared to I-level maintainers in MALS-13 that work almost exclusively with F-35s. When I-level technician support is required for MV-22 or H-1, VMX-1 requests personnel from units supporting RW or TR aircraft, like MALS-16 in Miramar, CA, or MALS-39, and the outside support increases the time required for repairs.

Aviation logistics support from MALS-13 works for VMX-1's F-35s, but outside of the two WTI courses annually, support is generally slower for MV-22 and H-1 aircraft. Furthermore, OT, while it is a critical step for getting equipment to the warfighter, does not have the highest force or activity designator (F/AD) rating or urgency of need designator (UND).

> An F/AD defines the relative importance of a U.S. force, unit, activity, project, or program to accomplishing DOD objectives. The principal purpose of the priority system is to differentiate between the relative importance of competing needs. F/ADs are used in conjunction with UND to establish a hierarchy of priorities used for supply requisitions. In an environment of limited supply resources, an organization's relative priority within the system is critical to its ability to secure its materiel requirements. As a result, organizations delegated the authority to assign F/AD designators III through V must assign designators appropriately to discriminate between forces, units, activities, projects, or programs. (Chief of Naval Operations, 2018, p. A-1)

The priority designator further amplifies the UND to determine where items are most needed to distribute them to that location first. The precedence for requisition processing and supply decisions is depicted with the matrix in Figure 5.

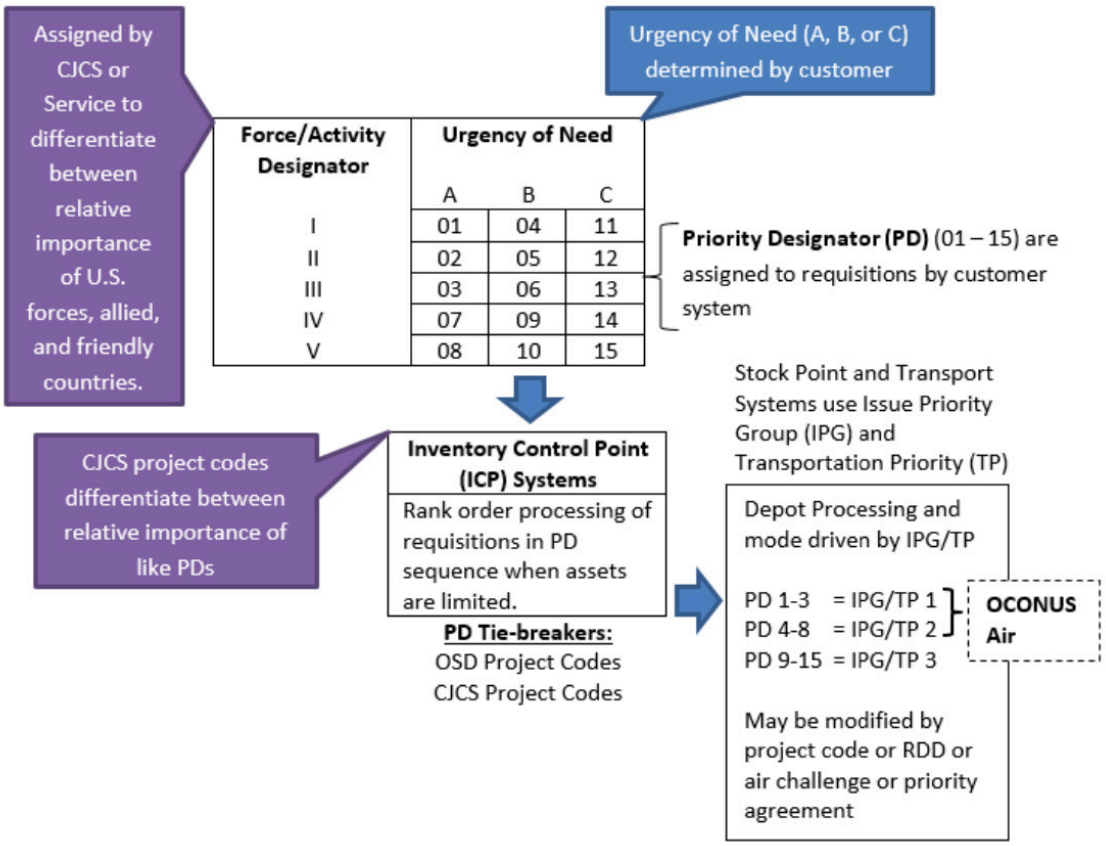

Figure 5. Precedence for Requisition Processing and Supply Decisions Matrix. Source: Chairman of the Joint Chiefs of Staff (2021, p. 2).

VMX-1 has the F/AD level of III, which includes units 31–90 days from deployment or "U.S. military programs or federal agency units and programs vital to DOD or national security objectives as determined by the Service Chiefs or CDRUSSOCOM, or commanders of affected CCMDs" (Chairman of the Joint Chiefs of Staff [CJCS], 2021, p. C-B-4). The F/AD I designator "may be assigned to programs that have been designated by the President or the SecDef as top national priorities" (Chief of Naval Operations, 2018, p. A-1). F/AD II is typically reserved for deployed units or units deploying within 30 days. Critical T&E may request a higher F/AD status for the duration of a specific test, and in those situations, VMX-1 would request a higher requisition status specified for the duration of that test window. Despite the higher parts priority, the geographic location of VMX-1 still causes delays, and having MV-22s and H-1s collocated

with other like-T/M/S squadrons increases the likelihood of possessing potentially needed parts when they are required.

3. Issues with Scheduling Resources

The unique nature of VMX-1 presents some additional challenges compared to the typical nature of fleet squadrons. A fleet squadron is guided by the deployment cycle, and the long-term picture is captured in the training and exercise employment plan (TEEP). The TEEP will show the proposed deployment and will capture any deployments for training or other milestones along the way to ensure the squadron is prepared to accomplish their mission. VMX-1 is not a deploying squadron, and the measure of success is completing OT&E reports. Each division within the squadron is concurrently working on various projects and balancing assets across shifting timelines. Presenting this information to all functional areas of the squadron is difficult, and the products to depict this information could be improved to enhance integration.

The squadron uses a long-range planning calendar (LRPC) to show upcoming test events broken down by week within the year and by aircraft. This is a Microsoft Excel document, and there are worksheets that provide additional information for events, like the specific configuration required or expected flight hours. The LRPC is the equivalent of a fleet squadron's TEEP. However, the culminating point for VMX-1 is not a deployment, but rather the test periods for each division. For this reason, the LRPC shows a lot of information, and one of the problems is that an effective program for depicting the details for scheduling long-range and short-range events does not exist.

The operations department and the OTDs work closely to ensure details for test events are communicated throughout the squadron. Information from the LRPC is transferred to separate shared Excel documents showing the monthly and weekly schedules. The information included on these products increases in the level of detail as the time proximity to the event approaches. The monthly and weekly products are best suited to compiling the information that will be listed on the daily flight schedule, which is a product signed by the commanding officer authorizing personnel to fly in squadron aircraft. However, there is no single product that can capture all the necessary information.

Over the past three years, VMX-1 partnered with the Air Force to contract a software scheduling program that would compile resource information and display it through scalable views of time windows. This product would allow users to input resource requirements that could be displayed and filtered to show conflicts with aircraft, personnel, or other potential issues. One of the problems with this program was that it was not compatible with the Marine Sierra Hotel Aviation Readiness Program (M-SHARP) and would create additional work for the individuals to input the data. M-SHARP is an aviation data management tool and provides the additional primary functions of "training management, risk management, T&R management and enforcement, flight hour management, and readiness management" (CMC, 2020, p. 2-22). It is directed for use for "all aviation flying and ground communities to plan, schedule, log, track, and manage their training and readiness requirements" (CMC, 2020, p. 2-21). To schedule personnel for flights, the user would need to search for information on M-SHARP and then input these data into the separate scheduling tool, which was already the process with the LRPC. The benefit of the scheduling tool was not worth the cost, and the squadron discontinued the funding for it and maintained the existing scheduling products. However, with the frequency of scheduled test events, limited manpower availability, and the demands for unique aircraft configurations and other requirements, the need for a single product that shows all assets available still exists for VMX-1 and would help identify resource constraints and potential conflicts.

B. TESTING PROCESS FLOW

Guidance for test for OTDs is provided in three publications from OPTEVFOR arranged by phase of test. The reports and products for each phase will be described in the following sections. Figure 6 shows the phases, some of which are overlapping, and the typical products completed during each phase.

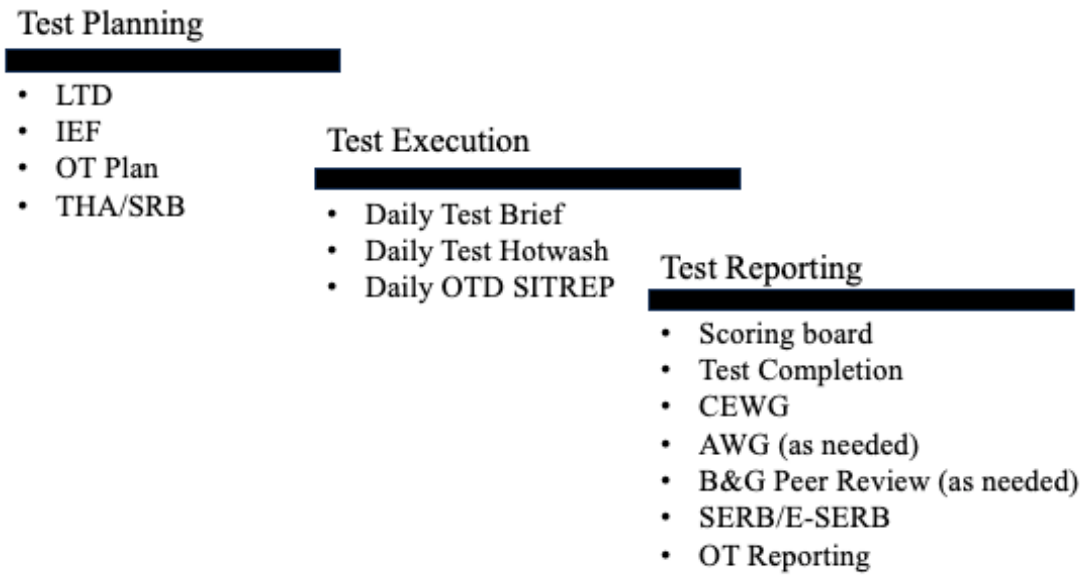

Figure 6. Test Process Flow and Typical Products. Adapted from OTE (2020a, 2020b, 2021b).

1. Test Planning

a. Level of Test Determination

The Level of Test Determination (LTD) is the key step in streamlining the acquisition process within the AAF by establishing OT involvement in testing. The possible outcomes from the LTD are: "no OT, observation of DT by OT personnel, or formal OT" (OTE, 2020a, p. 4-10). Organizations that are required to review testing requirements is dependent on the level of test. Common examples for LTD include: "Programs beyond IOT&E, when the need for FOT&E [Follow-on Test and Evaluation] is in question, ACAT IVM designations requiring COMOPTEVFOR concurrence letters, and Capabilities-Based Test and Evaluation (CBTE) test strategy development" (OTE, 2020a, 4-10). The determination sets the level of involvement for OTDs in VMX-1, and depending on personnel availability, OTDs will try to be involved in DT events before the LTD decision.

b. Integrated Evaluation Framework

Evaluating SUTs in OPTEVFOR begins with a thorough review of the test plan from the COMOPTEVFOR. Marine Aviation conducts several types of operational evaluations and reports, and many testing periods are heavily integrated with DT. To prepare for a successful testing period and quality reports, the Operational Test and Evaluation Manual defines Mission-Based Test Design (MBTD) and the Integrated Evaluation Framework (IEF) for OTDs. "MBTD is an iterative, systems engineering approach to designing OT that is mission-focused and executable by the operational tester. (OTE, 2021, p. 4-1)" The output of MBTD is the IEF, which is signed by the COMOPTEVFOR. Figure 7 shows the steps comprising the MBTD process that feeds the IEF and final OT products.

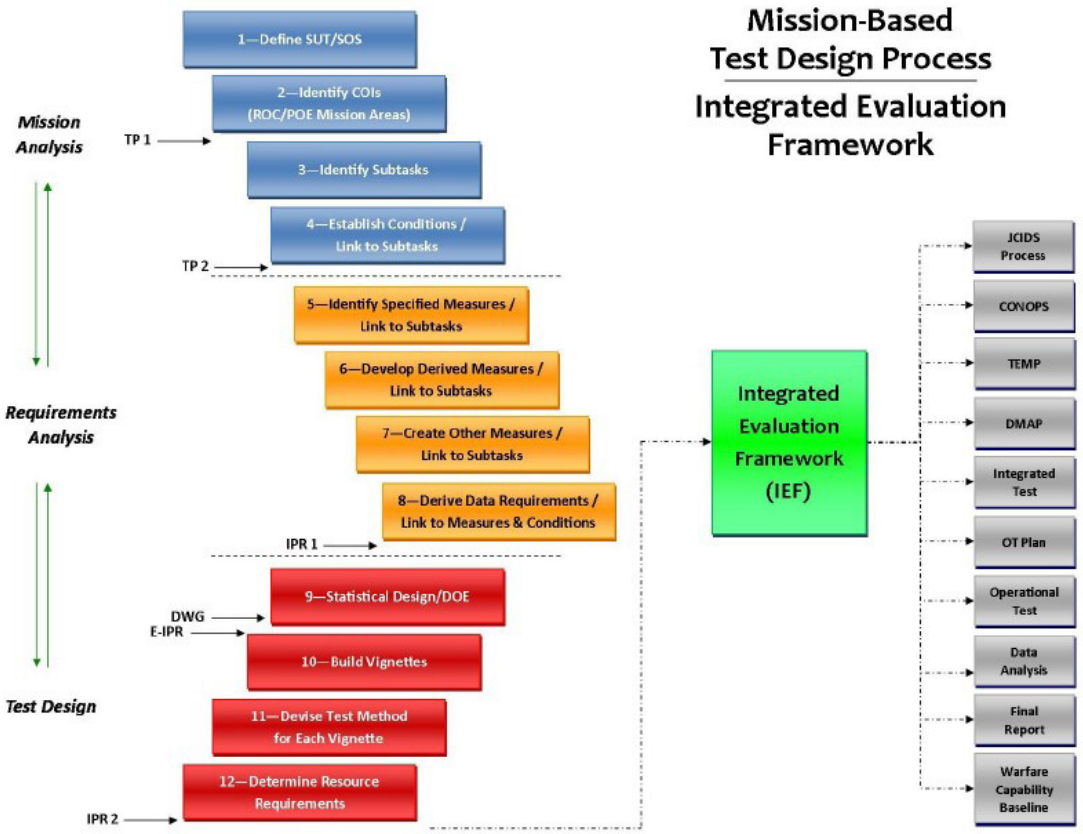

Figure 7. MBTD Process Flow Chart. Source: OTE (2020a, p. 4-1).

While developing the IEF, there are six decisional working meetings to "ensure stakeholder alignment and to provide course corrections to test teams when required (OTE, 2021a, p. 4-2)" These reviews include: Touchpoint 1, Touchpoint 2, In-Process Review (IPR)-1, Design of Experiment Working Group, Executive IPR, and IPR-2. The reviews differ in terms of leadership and stakeholder involvement, but the primary purpose is to create an IEF that "provides the OT measures, test vignettes, resources and other material required for TEMP [Test and Evaluation Master Plan] inputs and OT Plan development" (OTE, 2021a, p. 4-2).

c. Operational Test Plans

VMX-1 is involved in creating the IEF as the OT stakeholder, but most of the preparation from the OTDs takes place while creating the OT Plan. The Test Planning Handbook amplifies on the relationship of the IEF with planning for test. "While operational test planning may occur in parallel with the final stages of IEF development, OT planning cannot begin until all measures requiring Design of Experiments are fully described in the IEF" (OTE, 2020a, p. 4-1). The handbook recommends starting test planning seven months ahead of Oversight Programs and six months ahead of Non-Oversight Programs. The depiction of this timeline is included in Figure 8.

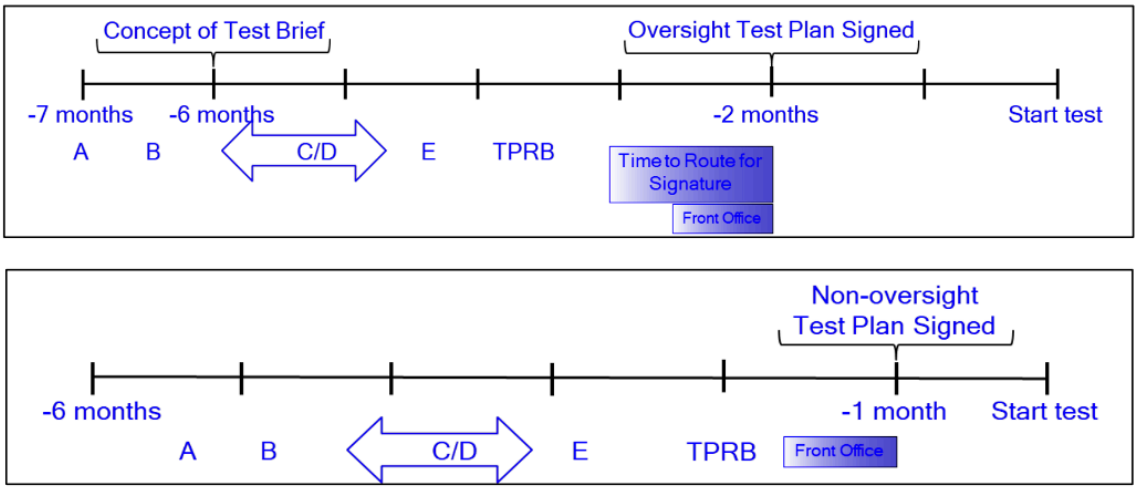

Figure 8. Notional Test Planning Process Timeline for Oversight and Non-Oversight Programs. Source: OTE (2020a, pp. 5-1–5-2).

Test planning involves touch points as well, but these are delineated alphabetically instead of numerically, like those in the IEF. The following paragraph summarizes the objective for each of the Test Plan Touch Points (OTE, 2020a, p. 4-2–4-10):

- Touch Point A: Define the Purpose of Test, including the SUT, System of Systems, Critical Operational Issues (COIs), and how the SUT's capability to accomplish the COI Critical Tasks will be evaluated.
- Touch Point B: Develop the Test Schedule and understand what data has been collected and qualified for OT, what data still need to be collected, and when those data will be collected.
- Test Plan Touch Point C: Develop the Detailed Method of Test for executing the test events detailed in the test schedule by determining how the test will be conducted and flow from event to event throughout the test phase.
- Test Plan Touch Point D: Develop the DCP (Data Collection Plan) in order to ensure all data requirements are linked to vignettes, test events, associated measures, and will be collected during test.
- Test Plan Touch Point D: Develop the DCP in order to ensure all data requirements are linked to vignettes, test events, associated measures, and will be collected during test.
- Test Plan Touch Point E: Develop the Data Analysis Plan to ensure the data is analyzed per the IEF and the Post-Test Iterative Process.
- Test Point Review Board: Gain approval from the Warfare Division Director for routing the draft OT plan for signature.

VMX-1 implements additional risk mitigation factors prior to test execution including a test hazard analysis and safety review board. The purpose of these measures is to align flight safety with that of the T&R Manual because the flight parameters of a specific test may be different than those described for a specific event for normal training. The safety documents will outline flight preparation for the aircrew to complete the specific

test. Additionally, if aircrew are not current and proficient in accordance with the T&R Manual, there will need to be a buildup to prepare for those OT events requiring flight.

2. Test Execution

The specific coordination for test execution like scheduling ranges and identifying any other required assets is conducted during the IEF and OT Plan preparation. Test execution relies on ensuring anything that changes fits within the scope of what was planned for the test and ensuring that items that drop out do not result in cancellation of the event. The Test Execution Handbook strongly encourages OTDs to "write everything down." (OTE, 2020b, p. 4-1). Other outputs from test execution include the Daily Test Brief, Daily Test Hotwash, and Daily OTD Situation Report (COTE, 2020b, p. 4-2-4-3). Any issues noted during test regarding risks or deficiencies are captured in "blue" and "gold" sheets for the Post-Test Iterative Process. "Blue Sheets" are for performance issues with the SUT, and "gold sheets" are for performance issues with the system of systems (OTE, 2021a, p.4-3). These performance issues and the raw data are provided to the PM with concurrence from the VMX-1 CO in a draft status.

3. Test Reporting

Test reporting completes the evaluation process to "classify performance issues, characterize risks/deficiencies, make overall COI assessments or resolutions, and make recommendations for each issue" (OTE, 2021, p. 2-1). The reporting steps are compiled into the Post-Test Iterative Process. The following are objectives for the post-test review (OTE, 2021b, p. 2-2–2-3):

- Scoring board: Reviews data collected to ensure it addresses measures delineated in test plan or DCP.
- Test Completion: Distributes a message or email communicating that no further data is required. If more data needs to be collected, the OTD will submit a planned timeline for test completion.

- CEWG (COI (Critical Operational Issues) Evaluation Working Group): Analyzes measures within the context of the COI and reviews deficiency sheets.
- AWG (Analysis Working Group): Convenes an additional working group if needed to further analyze data.
- B&G (Blue and Gold) Peer Review: Convene an additional review if needed to classify deficiency reports.
- SERB (System Evaluation Review Board): Reviews operational effectiveness and suitability, COI resolutions, and operational considerations. The Executive SERB includes senior leadership, and the inputs from the board are included in the final draft of the Test Report Letter.
- OT Report Documents: OTD routes rough draft of the Deficiency/Risk letter, the Data Analysis Summary memorandum for the record, and the Test Report Letter.

All products created by VMX-1 are routed internally and tracked through internal routing mechanisms. The status of active projects is submitted to the DCA on a bi-weekly basis. This update, known as the bi-weekly update, includes a description of the recently completed and upcoming test events for each department. An example of the Tests in Planning, Execution, and Reporting sections of the Bi-Weekly Update is depicted in Table 7.

Table 7. Bi-Weekly Update Table from 22 August 2022

Tests in Planning: (Note: indicates O-6 required)

Test Team	Test	Test Name	Last Planning Milestone Met	Date	Next Planning Milestone	Date	Test Plan Due Date
F-35	C2D2	30R08	Test Plan in Routing for Signature	22 Jul 22	Signature	TBD	-
F-35	EOT	GBU-53/B	none	22 Feb	Test Plan Review		22 Mar 22 Jun
F-35	None	RVL/EABO	Test plan workshop	22 March	Signature		22 Mar
H-1	OT-IIIE	DI	TPRB	29 June 22	Routing for Signature		22 Sep 22
H-1	IOT&E	DAIRCM POR	IPR-1	25 May 22	DWG	TBD	TBD
MV-22	IOT&E	IT-II (V)4	Touch Point B	17 Dec 20	Touch Point C/D/E	TBD	TBD
CH-53K	FOT&E	OT-D2	IPR-1	29 July 22	DWG	TBD	FY 24
CH-53K	FOT&E	OT-D3	IPR-1	29 July 22	DWG	TBD	FY 24

Tests in Execution: (Note: indicates O-6 required)

Test Team	Test	Test Name	Test Execution Start Date	Current Status	Test Completion Date
F-35	30R07	SDB-II DT Assist	13 Sep 22	Planning	13 Sep 22
F-35	EABO	RVL/EABO	15 April 22	Ongoing	TBD
MV-22	Demo	Blue Crayons	13 July 22	Ongoing	19-31 Aug

Tests in Reporting: (Note: indicates O-6 required)

Test Team	Test	Test Name	Last Reporting Milestone Met	Date	Next Reporting Milestone	Date	Test Report Due Date
MV-22	FOT&E	APR-39D(V)2	SERB	10 Aug 22	E-SERB	17 Aug 22	TBD
F-35	EABO	RVL/EABO	None	23 Mar 22	TTR #1	11 April	23 April 22
H-1	FOT&E	APR-39D(V)2	Scoring Board	31 May 22	CEWG	TBD	TBD
H-1	IOT&E	JAGM	ESERB	25 Mar 22	OTF Signed	8 June 22	31 May 22
CH-53K	IOT&E	OT-C1	SERB	7 July 22	ESERB	26 Aug 22	TBD

In each of the sections in the table, the event is listed with the previous milestone or upcoming due dates depicted. For the Tests in Planning section, the previous planning milestone's date is depicted with the upcoming test plan due date. Tests in execution are listed, and their status is described within the appropriate section of the Bi-Weekly Update. Tests in Reporting also show the status of the previous and upcoming milestone and associated due dates. In each of the sections, the light blue highlighted portions bring attention to milestones requiring O-6 action.

For each of VMX-1's projects, once squadron reviewers have screened documents, they are emailed to OPTEVFOR for further review. The OTE Manual states that

"T&E documents are routed at COMOPTEVFOR Headquarters within the Electronic Document Router in Knowledge Management System" (OTE, 2021a, p. 3-5). OPTEVFOR uses a program on the Navy computer network called iBoss, but the OTDs at VMX-1 do not have access to it because of network compatibility. There are several trackers for late documents within VMX-1 and OPTEVFOR, but there is no single database to determine submission timelines to identify potential hold ups during routing. Furthermore, there is no method to analyze trends to improve report routing and ultimately capabilities release to the fleet.

With the process flow and reporting actions described, the upcoming sections will discuss two VMX-1 projects to examine trends in test planning, execution, and reporting areas. There are many historical projects to choose from; however, to use recent examples with existing in-house knowledge from current OTDs, this capstone applied project will focus on the AN/APR-39D(V)2 Radar Signal Detecting Set (RSDS) for the MV-22 and Joint Air-to-Ground Missile (JAGM) for the AH-1Z. These two cases are selected because they highlight trends common to several projects conducted by VMX-1.

C. MV-22 AN/APR-39D(V)2 RADAR SIGNAL DETECTING SET

The AN/APR-39D(V)2 RDSD is an enhanced Radar Warning Receiver (RWR) suite for the MV-22. It is a component of the Integrated Aircraft Survivability Equipment (IASE) that serves to protect the aircraft from airborne and ground-based missiles and radar threats. VMX-1 conducted the integrated test in January 2018 and FOT&E for the system by conducting flight testing against known radar threats in a range space, as well as testing in a sterile anechoic chamber, and validating the metrics according to the signed OT Plan. FOT&E test execution commenced on 12 February 2019. During AN/APR-39D(V)2 testing, there was an issue in the anechoic chamber with the power supplied to the system, which required COTF approval to confirm the validity of the data for inclusion in the results. The testing for AN/APR-39D(V)2 occurred while the squadron was testing two other systems: another component of the IASE, the Department of the Navy Large Aircraft Infrared Countermeasures (DON LAIRCM) system, and the Intrepid Tiger-II system. For

manning requirements within the MV-22 projects division, the AN/APR-39D(V)2 testing became the priority for test execution and reporting.

The Bi-Weekly Updates showed test reporting beginning on 11 February 2022 with the OT Scoring Board 1 and Data Analysis Summary in work. The projects team conducted the CEWG on 23 February 2022, the SERB on 10 August 2022, and the E-SERB on 17 August 2022. The final signature for the test occurred in October 2022, three years after test execution began.

This project was in execution from February 2019 to February 2022. A significant portion of this is a result of the extensive data reduction and analysis requirement for the system. The AN/APR-39D(V)2 compiles electronic data from multiple sources including various buses within the MV-22 and a Mission Data Recorder installed into specified VMX-1 aircraft that captures time, speed, and position indication data. Other data is recorded and analyzed, including aircraft maintenance data, as well as range recordings of the aircraft during testing. Aircraft survivability equipment is upgraded through several iterations to provide better indications of enemy threats, but advancements in the commercial sector with cell phones and other devices, the signals environment is significantly more saturated with background clutter than when first versions of the RWR were developed. This is the main reason this system took three years for the Test Completion message to be released.

The deconfliction in priorities also demonstrates the limited personnel availability within VMX-1's Projects Divisions. The Assault Support Department has a civilian data analyst that compiles the data reduction from this flight test. The decision to prioritize AN/APR-39D(V)2 testing over DON LAIRCM and Intrepid Tiger-II resulted from limited OTD availability and the need for significant time investment to ensure all resources for the test are available and scheduled to avoid lengthy delays. There was personnel turnover within the division during this period, which dictates a transfer of information on the status of all test requirements. COVID-19 also played a role in the length of time for test reduction, as work schedules were affected for illness and other measures.

There were no significant delays as a result of aircraft availability for this test. One finding from this test was that the supply system supporting test operations was not fleet representative because the test concluded 19 months prior to the system material support date. It concluded that future logistics supportability will be evaluated in the next OT window (OTE, 2022a). During most test windows there is dedicated time to groom the required aircraft for test. Aircraft logistics support during test execution is provided differently than what occurs to prepare aircrew for flight proficiency. Outside of a test window, the squadron receives the typical aircraft maintenance supply support from MALS-13. In contrast, during the test window, the program office assists with support for the SUT. In this test it was not a factor, but delays in flight proficiency training could jeopardize test windows and incur greater risk during test execution.

The executive summary for this test concluded that the system was not operationally effective but was operationally suitable. The final recommendation is to not install the system until the identified severe deficiencies are corrected (OTE, 2022a). The AN/APR-D(V)2 was tested on several aircraft, and the full system was installed on the MV-22 for the test. The results from this report sent the system back to Northrup Grumman to correct, but the corrections are specific to the MV-22 platform.

D. AH-1Z JOINT AIR-TO-GROUND MISSILE

VMX-1 conducted the IOT&E for the JAGM to allow the system to enter full rate production in August 2022. The JAGM is an enhanced missile to increase commonality between several fixed-wing and rotary-wing aircraft in the joint services, including the AH-1Z, AH-64, and MQ-1 (Lockheed Martin, 2022). The program lead for the missile was the Army, but PMA-276 led the testing for the employment from the AH-1Z. VMX-1 conducted flight testing on the missile, and hosted operator and maintainer training to provide familiarization training for adjunct testers during the flight events. Once the testing was complete, OTDs familiar with the system flew sorties with fleet instructors to train them on the employment of the missile.

The TEMP for JAGM testing for the AH-1Z Cobra involved DT Support in the summer of 2020 and IOT&E in the fall of 2021. VMX-1 participated in the DT Support

and completed a letter of observation in February 2021. In May 2021, the H-1 OTD contacted PMA-276 to increase prioritization of parts for H-1s to groom the aircraft for upcoming testing events, including the JAGM IOT&E at Yuma Proving Ground, AZ and Eglin AFB, FL. Later that month, representatives from VMX-1 participated in a shareholder meeting to update the test schedule as a result of software issues and delays in the JAGM system. These software issues with the display of the seeker symbology resulted in test delays and the test dates at Yuma Proving Ground moved from August to December 2021.

The squadron conducted flight testing of the JAGM in Yuma in October, Eglin AFB in November, and completed the IOT&E at Yuma Proving Ground in December. For the testing at Eglin, the squadron pursued strategic lift of the aircraft and detachment to preserve aircraft hours by transporting the aircraft in a C-17 or C-5 aircraft. VMX-1 does not have a Mobility Officer assigned to the unit, so the Operations and Logistics Departments coordinated with MAG-13 for transportation of the testing detachment. Ultimately, strategic lift was not available because of higher priority tasking. Maintenance ground support equipment and other large cargo was transported via truck, personnel were flown via Marine KC-130J aircraft, and the test H-1 aircraft conducted a multi-day cross-country flight to Florida. Test aircraft do not fly much ahead of test events, and the lengthy transit to and from the testing destination caused the test to incur added risk by flying 78.1 hours on the aircraft. Furthermore, after the aircraft flew back to Yuma, there were only a few weeks with a Thanksgiving holiday period to repair the aircraft and prepare for the second round of testing at Yuma Proving Ground.

Data reduction and analysis occurred following the flight tests, and the Test Completion message was released in March 2022. Following test completion, the SERB and Executive SERB were complete by the end of March 2022. The Commander of OPTEVFOR signed the Test Report on 8 June 2022 with IOT&E for the system complete in August.

OT for the JAGM has similar overinflation of system readiness to that of AN/APRD(V)2, and software modifications delayed the initially planned test period. The final report assessed the effectiveness that "left operators little spare capacity for other tasks

(OTE, 2022b). The seeker symbology issues should have been resolved during the system's DT, but the updates occurred during OT and required the test to slide. Higher F/AD status requests and communication with PMA-276 for parts priorities facilitated the aircraft logistics support to groom the aircraft for the tests and cross-country flights. Squadron manning is an issue, because the Logistics Officer at VMX-1, as well as most fleet aviation units, is not trained in logistics, nor do they have an extensive background in logistics planning. Logistics officers in aviation units are pilots. For VMX-1, mobility and logistics officers in adjacent units are needed for large testing detachments. Lastly, delays in testing require the OTDs to do extensive coordination to adjust range times and shift support from outside entities.

E. COMMON TRENDS

For these two test examples, as well as many other tests, there are intangible infrastructure issues that do not cause extensive delay for test events, but they do stress the planning or execution phases for the OTDs. These include getting access for contractors or visitors supporting an event or experiencing problems with vetting individuals for appropriate security access. Network latency also causes OTDs and other personnel in the squadron to work longer hours on a daily basis which in turn depletes human capital.

VMX-1 supplements officer shortfalls with contractors and civilians, but the organization within the unit outlines billets for pilots in which they are not trained to do. Recently in the squadron, a UAS pilot laid the groundwork for the creation of a sensitive compartmented information facility in the squadron's new hangar with no previous experience in that area. Additionally, the high turnover rate of personnel in the squadron often results in different OTDs completing the test reporting than those that started the test planning. The need for adequate training in each of the different phases takes time, so getting the right individuals into place and assigning them to a project early allows consistency throughout the milestones and lifecycle.

There is a consistent overinflation of systems that come to test. When a system leaves DT, it is assigned a severity for each deficiency, and the Operational Test Readiness Review determines if the system is ready for OT despite deficiencies. No decision is

perfect, and there are acknowledged risks with allowing an underperforming system to progress. Those systems end up placing an additional burden on OT to determine if the system is ready, rather than solely evaluating effectiveness and suitability. For AN/APRD(V)2 testing on the H-1, the system would frequently overheat, which delayed further testing until the developer modified the system. In 2020, when the MV-22 division was assessing the AN/APRD(V)2, the OTDs conducted a QRA (Quick Reaction Assessment) of the Mesh Network Manager (MNM) for Digital Interoperability (DI). The MNM system went on to be fielded to fleet MV-22 squadrons, but still requires frequent involvement of the contractors to show squadrons how to set it up and use it. The established requirements for DI are fulfilled, but the suitability and ease-of-use metrics were not codified into the requirements. This added requirement for ease-of-use would allow the capability to not be so challenging to achieve for squadrons without outside contractor support.

Issues associated with immature systems are unavoidable, but reporting is something the squadron can affect and continue with higher agencies. For systems like the AN/APRD(V)2, there is a significant amount of data that needs to be reviewed to form solid conclusions for the Data Analysis Summary. Once the data is summarized, report routing can be delayed depending on how many individuals are required to review it. Accountability and metrics for determining how long a report is sitting awaiting guidance would increase reporting timeliness. Another way to improve timeliness is to better assess which programs require full OT involvement, and this is determined in the LTD. Facilitating entry into the AAF will streamline the reporting requirements, because there are fewer entities involved to allow for more rapid capabilities acquisition.

F. AAF APPLICATIONS

The squadron has not yet completed programs in an abbreviated acquisition timeline in the AAF. For OTDs, the process flow for AAF programs and those requiring full OT would require similar products, but there would be fewer steps in the routing process before final release. There is a simplified acquisition management plan for Group 5 UAS with MQ-9, or MUX-MALE (MAGTF UAS Expeditionary Medium Altitude, Long

Endurance) system. This family of systems in development will provide airborne network expansion early warning, maritime domain awareness, electronic warfare support, C2, and beyond line-of-sight data dissemination (Naval Air Systems Command PMA-266, 2022). When applicable, it is important to assess the systems separately to expedite the fielding of the individual capabilities, rather than test and release the entire system as a whole. For MV-22 OT, there were several systems combined into OT-IIIK (OTE, 2017). When the Defensive Weapon System and Ramp Mounted Weapon System for the aircraft were delayed, it caused the other components of OT-IIIK, specifically the Mission Computer upgrade to be delayed as well.

With an LTD decision to separate an applicable systems and field it separately, program cost is divided, and higher approval and signature authority is reduced to a lower level. Higher cost programs are under increased scrutiny, and the Defense Acquisition System is established so there are more checks and balances during testing. Carefully selecting which programs are admitted into AAF and lowering the threshold and separating components of a system would allow for a more streamlined acquisitions approach. With more programs inducted into the AAF, the squadron would be tasked to complete more QRAs for abbreviated OT and expedited capabilities release.

G. CHAPTER SUMMARY

This chapter examined the resource shortfalls for the squadron and the process flow and typical products for OTDs. OTD involvement begins early as a stakeholder and increases depending on the requirements established in the OT Plan. VMX-1's previous projects of the MV-22 AN/APRD(V)2 RSDS and AH-1Z JAGM highlight the common resource shortfall trends for OT programs of infrastructure deficiencies, manning shortfalls, underestimated TRLs, insufficient requirements definitions, and delays in reviewing reports. Infrastructure and manning are institutional issues for the Marine Corps and are being addressed with contractor support within VMX-1. The other trends require dedicated training from all acquisition professionals and consistent foresight from the planners to top levels of leadership to provide the warfighter with the capabilities needed for the future fight.

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V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

While VMX-1 is a unique aviation unit within the Marine Corps, it faces similar challenges to fleet units including manning, aviation logistics support, and adequate scheduling resources. The previous chapter examined the process flow for OTDs through the test planning, execution, and reporting phases for the various tests in which the squadron is involved. Analysis of the test reports and bi-weekly updates for the AN/APR-39D(V)2 for the MV-22 and the JAGM for the AH-1Z highlighted common trends between the two described tests and other projects for the squadron. Issues with infrastructure deficiencies, manning shortfalls, underestimated TRLs, insufficient requirements definitions, and delays in reviewing reports challenges OTDs from each T/M/S in the various phases of test, and they must work creatively to address those challenges and balance the objectives of the test.

B. CONCLUSIONS

For the primary research question of "How should Operational Test and Evaluation be adequately resourced in Marine Aviation and what are the best ways to optimize efficiency to determine additional test capability for the squadron?" The mission of the squadron is to conduct OT, and the process flow for OT is broken down into the three phases of test. While additional officer and enlisted manning would improve both the testing capacity and maintenance output, improving communication within the squadron ensures focus of effort on various tests within the squadron's current staffing. For VMX-1, coordination during the test planning and execution phases is compiled though the OTD and communicated through the Operations Department and the LRPC. Test statuses are described in the bi-weekly updates and routed through squadron reviewers prior to be sent to OPTEVFOR. Timely reporting is something the squadron can affect and continue with higher. Additionally, OTDs should be assigned as a primary to a project and carry the project through as much of its lifecycle as possible during their assignment to the unit. This requires assigning officers as OTDs early when they arrive to the squadron and sending

them to the OPTEVFOR courses. This will allow them to build experience and keep familiarity with the system being tested.

The secondary questions of identifying problem areas that would improve efficiency and comparing the OT planning process flow for programs in each of the AAF pathways were similar, because the squadron is only recently becoming involved in a simplified acquisition program with the MUX-MALE system of systems. The best way to increase the speed of capabilities to the warfighter is to reduce the testing requirements, and this decision is completed ahead of typical OT involvement during the LTD. When appropriate, the system should be viewed separately from the vehicle. However, for systems like the JAGM on the AH-1Z and the AN/APR-39D(V)2 on the MV-22, platform specific issues require significant attention to make a system compatible to each type of aircraft. Therefore, it would be beneficial to wrap abbreviate the acquisition process for systems on an existing vehicle, but it would increase the risk that an inadequate or unsuitable system would be fielded. Each system needs to continue to be carefully scrutinized for the potential entry into AAF.

C. RECOMMENDATIONS TO IMPROVE VMX-1 OT

1. Continue to improve the scheduling tool to ensure communication, information flow to all squadron departments, and adequate preparation for all test assets.
2. OTDs should be assigned for their entire tenure in the squadron to allow them to be adequately trained and gain experience. Each OTD should be assigned as a primary to a project and guide the system through OT during their tenure in the squadron.
3. Submit a TOECR for RW/TR personnel to be assigned to MALS-13 to assist with H-1 and MV-22 maintenance actions for VMX-1. I-Level contractor support can also be levied to fill the geographical shortfall.
4. Carefully scrutinize systems for the potential entry into abbreviated acquisition.

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