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TUAVs:

The Future Eyes of Canadian Maritime Defence

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Abstract

This paper argues that Tactical Unmanned Aerial Vehicles (TUAVs) are an essential maritime aviation complement to Maritime Helicopters (MH) within the Canadian Navy. They are complementary as there are certain key tasks that the Navy needs that require an MH and there are times when a human on the scene is crucial to situational awareness. That said, TUAVs contribute across the spectrum of conflict in an efficient, flexible and affordable manner. Unmanned, TUAVs enable a commander to risk assets for mission accomplishment vice lives. Their advanced payloads offer certain capabilities and efficiencies beyond what the MH can. Further, TUAVs can advance CF Joint operations and further improve DND support to Other Government Departments, most notably in maritime security initiatives. There are challenges to TUAV integration in terms of infrastructure, personnel, and resource management. However these challenges are more than offset by TUAV support to high-risk operations, improved CF capability, Joint operations support, and long-term life cycle economies for both CF TUAVs and MHs. The CF should aggressively pursue acquisition of TUAVs for the Navy in step with the MH acquisition, Joint Support Ship design, and HALIFAX class midlife FELIX upgrade.

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Scenario 1. On an international Operation, HMCS ALGONQUIN launched her UAV to maintain constant surveillance of the maritime interdiction area. The UAV detected smuggler traffic, which was then intercepted by coalition forces. The presence and extensive long-range UAV surveillance provided excellent information and Command situational awareness. This contribution earned **Diplomatic** visibility for Canada.

Scenario 2. HMCS VANCOUVER and her UAV effectively supported the Canadian Immigration Commission in intercepting illegal migrants destined for Canada. The UAV detected the vessel of interest and then transmitted near real-time information for evaluation at the Maritime Operations Security Information Centre (MOSIC) in Ottawa. Within hours, VANOUVER was ordered to intercept the COI in support of her **Constabulary** role.

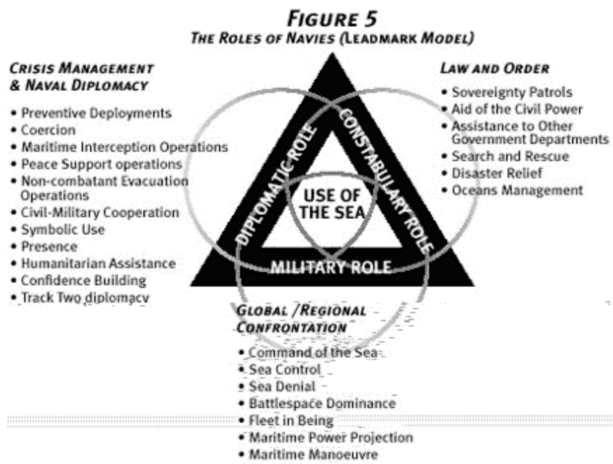

Figure 1: Leadmark 2020 Naval Roles[1]

Scenario 3. During open hostilities, the Canadian Task Group launched a UAV to find and attack the enemy at long range. The UAV detected the enemy force, relaying the targeting position to the Task Group. As the UAV remained undetected because of its low altitude and small radar cross-section, the Task Group was able to successfully attack first with Harpoon at long range. The unmanned UAV instantaneously assessed the **Military** engagement at no risk to human life

[1] Department of National Defence, *Leadmark: The Navy's Strategy for 2020* (Ottawa: DND Canada, 2001), 34.

Chapter 1

Introduction

The scenarios described are not science fiction. Not only are they not science fiction, they are achievable with the Tactical Uninhabited Aerial Vehicle (TUAV) technology available today.[2] The capabilities inherent in this affordable, advanced, and flexible organic maritime air asset are considerable and merit an in-depth look to consider how they may support the resource needs of a medium power navy such as Canada's.

UAVs and TUAVs are now part of the modern military's toolbox. They have been operationally employed most recently in Afghanistan and Iraq where they significantly contributed to situational awareness and the common operating picture. UAVs and as indicated at Table 1, TUAVs are also either under development or in use by the United States, Germany, France, and Great Britain amongst others in naval roles such as naval gunfire spotting, surveillance, and intelligence collection.[3] Finally, a key enabler within the United States Coast Guard's (USCG) Integrated Deepwater project, they will be employed in support of maritime safety, security, mobility, national defense, and protection of natural resource missions.[4] Thus, UAV and TUAVs are currently

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[2] Tactical UAVs have lower operating ceilings and shorter endurance than Medium Altitude Long Endurance (MALE) and High Altitude Long Endurance (HALE) UAVs such as Predator and Global Hawk. Further, their concept of operations directly supports the Task Group or unit Commander's requirements and as such is not a theatre controlled resource.

3 Douglas Barrie, "UAVs Go Global," Aviation Week & Space Technology, Vol 159, Issue 11, 15 September, 2003: 40-42. United States. Office of the Secretary of Defense. Unmanned Aerial Vehicles Roadmap 2002-2027 (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 21.

4 United States. United States Coast Guard. Integrated Deepwater Project. Available from http://www.uscg.mil/deepwater/challenge/missions.htm; Internet; accessed 8 March 2004.

supporting or will imminently support military, diplomatic, and constabulary roles worldwide.

SELECTED MILITARY RECONNAISSANCE UAVS

	TACTICAL		SPECIALISED		ENDURANCE	
Country	Over-the-hill	Close-range	Maritime	Penetrator	Medium-range	Long-range
USA	Pointer	Hunter/Shadow	Fire Scout	X-45/X-47	Predator	Global Hawk
France	Lulleby	Crecerelle/Sperwer	Marvel	CL-289	Eagle 1	
Germany	KZO/Taifun/MAV1	Brevel	Seamos	CL-289/Surveyor		Euro Hawk
UK	Sender/Observer	Phoenix				
Italy	Dragonfly	Mirach 26		Mirach 150	Predator	
Israel	Eyeview/Skylark/ Seagull	Searcher/Hermes 450/ Hermes 180			Heron/Hermes 1500	
Russia	R90	Shmel/Yak-61		VR-3 Reys/ VR2 Strizh		

Table 1. Selected Military Reconnaissance UAVs.[5]

At home, Canada has begun considering and evaluating UAV and TUAV technology, both nationally and in conjunction with other nations, with a view to determining the possible applications and roles that they could support within the Canadian Forces.[6]

This paper will argue that TUAV's are an essential organic maritime aviation complement to maritime helicopters (MH) within the Canadian Navy. It will also demonstrate that the integration of TUAVs within the Navy is achievable largely within the existing infrastructure and that CF should aggressively pursue a TUAV capability. In so doing, this paper will address the fundamental question of why limited resources should be put into TUAVs when the Navy will maintain an organic MH capability. It is not the intention of this paper to indicate which TUAV the CF should purchase. This

[5] Oliver Sutton, "Mission dull, dirty, or dangerous? Call up a *UAV,*" *Interavia Business & Technology* Vol 58, Issue 672 (July – September 2003): 40-46.

[6] The CF Experimentation Centre operated one mini, tactical, and medium altitude TUAV during trial Robust Ram at CFB Suffield in 2002, deployed one medium altitude TUAV in direct support to the Land Combat Commander for the Kananaskis B.C. G8 Summit, and operated one medium altitude TUAV during Pacific Littoral in 2002

restriction on the scope of analysis is practical as, notwithstanding significant advances in TUAV capability and design, many aspects of the technology are just now fully maturing (e.g. at-sea small deck launch and recovery systems, increased mission reliability etc.).

In arguing that TUAVs are the future eyes of Canadian maritime defence, this paper will commence with a brief historical review of TUAV employment. It will also consider where the CF is with respect to UAV and TUAV development, testing, and operational use. Next, the ship borne maritime surveillance capability requirements of the CF will be examined. These requirements will be compared against the MH Statement of Operational Requirement (SOR) capabilities and current and anticipated TUAV capabilities to draw attention to each platform's relative strengths and what TUAVs in particular bring to the fight. A discussion on TUAV concepts of operation and support will highlight that TUAV integration into the Maritime Air Group and the Navy is both feasible and, with a m complementary and necessary to the Navy's ability to meet its roles in the Domestic, Continental, and International operating environments.

The time to get into the TUAV game is now…

Chapter 2

Historical Perspective

During the Second World War, the aircraft carrier effectively replaced the battleship as the dominant sea combatant. Its ability to launch and recover aircraft to search, identify, track and attack targets, both ship and ashore, revolutionized the manner in which warfare was conducted, greatly surpass the capability resident in large combatants with one or two deck catapult-launched sea planes. In 1967, the Canadian Navy added a hanger and a maritime helicopter to the St. Laurent class destroyer. The class was renamed the Improved St. Laurent (ISL) and the adaptation was to become a standard design feature in major warships in many navies. The addition of a helicopter to non-aircraft carrier warships greatly increased the surveillance range and overall capabilities of a Task Group (TG) at-sea. Just as the aircraft carrier and the ISL dramatically changed the character of naval operations and capabilities, the TUAV represents the next potential step in maritime air.

Military application UAV variants (e.g. Falconer, Bikini, Osprey, Lightening Bug) have been employed since the 1950's performing largely reconnaissance missions.[7]

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[7] Christopher Jones, USAF Maj. "Unmanned Aerial Vehicles (UAVS) An Assessment of Historical Operations and Future Possibilities." (research paper, USAF Air Command and Staff College,

As the technology has matured, High Altitude Long Endurance (HALE) and Medium Altitude Long Endurance (MALE) UAV's have conducted Intelligence, Surveillance, and Reconnaissance (ISR) operations in Iraq, Bosnia, Kosovo, and Afghanistan and combat operations in Yemen and Afghanistan.[8] In a maritime context, the U.S. employed the Pioneer TUAV as a battleship gunnery-spotting vehicle, and for amphibious reconnaissance and surveillance missions where it became the first TUAV system to receive a surrender (in this case from Iraqi troops during DESORT STORM).[9] Recently, medium powers such as Australia have deployed UAVs (Aerosonde Ltd's Aerosonde) in support of operations in the Solomon Islands.[10]

In Canada, the CF has not missed the significance of this emerging and very promising technology and is pursuing trial and limited operational use. In 2003, the Canadian Army purchased an Oerlikon Contraves' Sperwer UAV system to support Canadian-led United Nations ISAF operational requirements in Afghanistan and fulfill a

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March 1997), 4. United States. Office of the Secretary of Defense. Unmanned Aerial Vehicles Roadmap 2002-2027 (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 25.

[8] In 2002, a Predator UAV conducted precision strikes against terrorists in Yemen and Hellfire missile attacks in close air support of ground troops in Afghanistan. The operator in the Afghanistan engagement was awarded the Silver Star for his actions. Lynda Hurst, "U.S. arsenal deadlier than ever; Pentagon readies high-tech systems for use in Iraq But all bets off if fighting moves to crowded Baghdad," Toronto Star. 22 December, 2002 and Ted McKenna, "Cleared for Action: Incorporating UAVs into the Battlespace," The JOURNAL of ELECTRONIC DEFENSE, (September 2003) [journal on-line]; available from http://jedonline.com; Internet; accessed 15 March 2004.

9 United States. Office of the Secretary of Defense, Unmanned Aerial Vehicles Roadmap 2002-2027 (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 6 and E.R. Hooton, "Maritime Drones – Back to the Future?" ***armada*** *International* (1/2004): 61-62.

10 Gregor Ferguson, "Aussie First: Operational Deployment of UAVs," The JOURNAL of ELECTRONIC DEFENSE, (September 2003) [journal on-line]; available from http://jedonline.com; Internet; accessed 22 April, 2004.

commitment Canada made to NATO to obtain UAV capability by 2004.[11] Recent Commander of ISAF, MGen Leslie, valued greatly the ISR information that the Sperwer TUAV was able to collect. Further, the TUAVs ability to conduct these missions over potentially hostile terrain removed the need to traverse dangerous ground unnecessarily, reducing the risk to his soldiers considerably.[12] The CF Experimentation Centre has also recently conducted test exercises Robust Ram and Pacific Littoral and has operationally employed MALE UAVs in support of the Land Component Commander's security requirements during the Kananaskis G8 Summit.[13] From a Navy perspective, the July 2003 Pacific Littoral was a very positive experiment. During experiment flight 2, a vessel suspected of a pollution violation was detected by the trial Israel Aircraft Industries (IAI) leased MALAT Eagle 1 UAV. The UAV payload provided "positive identification of the suspect and colour imagery of the suspicious emissions which were turned over to Transport Canada thru the Operational Support Centre Pacific."[14] This

[11] Brendan P. Rivers, "Canadian Forces Acquiring UAVs," The JOURNAL of ELECTRONIC DEFENSE, (October 2003) [journal on-line]; available from http://jedonline.com; Internet; accessed 25 March, 2004.

12 MGen Leslie, A/COS CLS and recent UN ISAF Commander, Canadian Forces Command Staff College presentation, 26 April 2004.

13 OP GRIZZLY was the CF's largest domestic operation. It involved the deployment of close to 6,000 troops in support of the Kananaskis G8 Summit in June 2002. UAVs were successfully used to conduct perimeter surveillance. Canada, Department of National Defence, A Survey of Experimental UAV Squadrons in Exercise Robust Ram and Operation Grizzly: Research Note RN 2003/05 (Ottawa: Operational Research Division Directorate of Operational Research (Joint) DND Canada, September 2003); Available from VCDS PART II: 2002-2003 performance highlights http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/ddm/dpr2003/dpr-2a3_e.asp ; Internet; accessed 15 February 2004.

[14] Canada, Department of National Defence. Experiment Report – 001/2003 (QUICKLOOK) pacific Littoral ISR Experiment – Part 1. Ottawa: DND Canada 2003, 3.

event effectively demonstrated the capabilities resident in advanced payload systems[15] and was a telling example of how UAVs can improve the Navy's ability to support Other Government Departments (OGDs) in a constabulary role. Finally, the Navy leased and employed the VINDICATOR drone target in 2002 to support naval gunnery training. Launched from both MCDV and HALIFAX class warships, the VINDICATOR was controlled by the same system that controls the BARRACUDA remote surface maritime gunnery target.[16] On mission completion, the VINDICATOR was commanded in-air to shut down and deploy its parachute for water entry and subsequent recovery. An excellent alternative to shore-based target training aircraft, the VINDICATOR target provided flexibility, affordability, greater realism, endurance, and immediate gunnery result information to exercising units.[17]

The Revolution in Military Affairs has recognized the potential of UAVs, which are now being employed by major and medium power militaries in operations, including Canada.[18] Their contribution in operations, from intelligence collection and surveillance to attack, has established their utility in the military arena. From a Canadian Navy perspective and considering operational contributions to date, the two experimental trials,

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[15] The Eagle, a MALE, was equipped with an ELTA 2022 Maritime Patrol Radar (that also has a weather and air-to-air display modes) and the Malat Multi-Mission Optronic Stabilized Payload (EO/IR steerable ball).

[16] The BARRACUDA is essentially a ship-launched, remotely controlled speedboat with an enhanced radar signature that Canadian Navy ships practice live gunnery firing on.

[17] The author was involved in the use of the VINDICATOR drone as a live gunnery target and simulated missile training. The VINDICATOR provided an excellent level of live gunnery training and immediate gunnery feedback.

[18] The CF RMA Operational Working Group recognized countries such as the Great Britain and France are actively pursuing UAV technology. Department of National Defence. *Canadian Defence Beyond 2010 The Way Ahead: An RMS Concept Paper* (Ottawa: RMA Operational Working Group DND Canada, 1999), 4-5/42.

Pacific Littoral and the lease of the VINDICATOR, practically demonstrated the flexibility and utility of UAVs and clearly signify their potential in meeting the Navy's roles.

Chapter 3

Environment & Aviation Roles

Section 1: Introduction

Canada's extensive 240,000 km coastline[19] presents both opportunity and challenge in terms of security, resources, and trade and thus makes the continental maritime environment of considerable strategic importance for Canada. Equally, as an active member of the international community, Canada promotes national interests through participation in United Nations, alliance, and coalition diplomatic and military operations. This chapter will consider the domestic, continental, and international maritime environments and how various OGDs are adapting to the maritime security environment post 9/11. It will then examine the Navy's mission to emphasize how organic naval aviation is a force-multiplier and how its use relates to the three naval roles outlined in Leadmark, namely Constabulary, Diplomatic, and Military.

[19] Department of National Defence, *Leadmark: The Navy's Strategy for 2020* (Ottawa: DND Canada, 2001), 2.

Section 2: Maritime Strategic Environment

The 1994 Defence White Paper (DWP) assessed that while there was no immediate direct military threat to Canada, it was necessary to maintain a prudent level of military force to deal with challenges to our sovereignty in peacetime and to participate effectively in multilateral peace and stability operations.[20] In considering the spectrum of conflict that the CF could become involved in, the CF has derived eleven force-planning scenarios against which "CF capability requirements and force structure options will be assessed."[21] The eleven force-planning scenarios from the Defence Planning Guide 2001 are delineated at Table 1. These scenarios describe operations from peacetime national support (e.g. Search and Rescue (SAR)) to full fledged combat operations and serve as a measure when designing CF force structure requirements. The scenarios will also be used later in the paper to show how TUAVs can effectively meet the Navy's requirements.

No.	Scenario	Summary
1	Search and Rescue in Canada	Sub-scenarios include rescue from a ship at sea, search and rescue of an overdue hunting party in the North, and the rescue of survivors from a major airliner downed in a remote area in the North.
2	Disaster Relief in Canada	Assist in the relief of human suffering and assist authorities to re-establish the local infrastructure after a major earthquake on the west coast of Canada.
3	International Humanitarian Assistance	As part of a UN operation, assist with the delivery of relief supplies to refugees amassed in a central African nation.
4	Surveillance \ Control of Canadian Territory	Assist Other Government Departments and law enforcement agencies in identifying, tracking and, if required, intercepting platforms suspected of carrying contraband goods or illegal

[20] Department of National Defence, *1994 Defence White Paper* (Ottawa: Canada Communications Group, 1994), 21-22.

[21] Department of National Defence, *Defence Planning Guide 2001* (Ottawa: DND Canada, 2001), Chapter 2, article 210, para 5.

[redacted]	mmigrants before or after entering Canadian territory.
[redacted]	ssist DFAIT, as part of a combined force, in the protection nd evacuation of Canadian nationals in a foreign nation hreatened by imminent conflict.
[redacted]	articipate as part of a UN peacekeeping force maintaining a ease-fire and assisting in the creation of a stable and secure nvironment where peace building can take place.
[redacted]	ssist civil authorities in the establishment of law and order in n area where lawlessness has occurred as the result of disputes ver the control of water rights in a time of severe drought.
[redacted]	laiming extended jurisdiction under UNCLOS III, Canada has equested the cessation of seabed exploitation operations by a oreign nation. The CF will assist OGDs in the enforcement of anadian claims.

Tw 12 0 0 12 1 47g260.0099 Oon operati of C territorial waters, and the economic exclusion zone (EEZ) to meet their respective mandates. The Navy's domestic involvement, referred to as the constabulary role in Leadmark, is further elaborated upon in force planning scenarios, the Defence Plan Online 03/04, and the Canadian Joint Task List (CJTL). In these situations, the OGD is the lead agency with DND 'enabling' the respective OGD to exercise their domestic mandate on behalf of Canadians (e.g. transporting and supporting RMCP, Department of Fisheries and Oceans (DFO), Canadian Immigration Commission (CIC) teams).

Continentally, the 1994 DWP charged DND to operate with U.S. forces to defend North America.[24] Canada's 1958 NORAD alliance with the U.S. to, "Deter, Detect, Defend"[25] the airspace of Alaska, Canada and the contiguous 48 United States is a tangible example of that commitment. Post 9/11, it is now more than ever, essential that Canada continue to work to with the U.S. to further improve CANUS continental security initiatives and capabilities (including maritime). This is vital for two reasons. One, it will serve to combat terrorism while having the spin-off benefits of deterring organized crime, illegal immigration, illegal fishing etc. Second, it will convince the U.S. that Canada is not a soft underbelly, thereby avoiding any risk or effect on cross-border trading or other negative effects on the CANUS relationship.[26] Canada's ability to

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[24] Department of National Defence, *1994 Defence White Paper* (Ottawa: Canada Communications Group, 1994), Chapter 5.

[25] North American Aerospace Defense Command, available from http://www.norad.mil/index.cfm?fuseaction=home.welcome; Internet; accessed 10 February, 2004.

[26] As highlighted in Strategic Assessment 2020, terrorist activities and the perception of terrorist modus operandi can negatively affect the Canada / U.S. dynamic and trade. The arrest of Ahmed Ressam in December 1999 for attempting to cross from Canada to the U.S. with explosives created a minor diplomatic incident. As well, in the aftermath of 9/11 when the U.S. cited concerns that the highjackers arrived into the U.S. through Canada, the U.S. unilaterally tightened border control, significantly impacting cross-border flow. Department of National Defence, S*trategic Assessment 2002* (Ottawa: DND Canada, 2003), Functional Issues – Homeland Security.

provide effective surveillance and control over continental maritime areas is key to continental defence and national interests.

From an international perspective, Canada is a nation that has prided itself on working within the global community to promote world stability while advancing its interests and values. As a nation, we are more secure by addressing the resolution of global problems at their source before they threaten Canada.[27] Membership and active participation (e.g. by providing highly-trained and well-equipped combat capable forces) within the UN, NATO, and coalitions are indications of Canada's active involvement in supporting global stability and national interests.[28] In particular, Canadian naval participation has been a prominent tool in the government's toolbox when deciding how to best contribute as evidenced in many of the recent major operations.[29] In addition to the classic reasons of why naval power is a foreign policy tool of choice,[30] the Navy's ability to quickly integrate and very positively contribute to the (coalition) Recognized

[27] Sean M. Maloney, "Helpful Fixer or Hired Gun: Why Canada Goes Overseas," *Policy Options Politiques* Vol 22, No 1 (Journal of the Institute for Research into Public Policy) (January – February 2001), pp.59-65.

[28] In addition to participation in UN and coalition operations, Canada has contributed a frigate as an integrated unit of U.S. Carrier Battle Groups on Arabian Gulf deployments during OP MERCATOR, OP AUGMENTATION, OP APOLLO, and OP ALTAIR.

[29] In the past 15 years, the Navy has participated in many high profile diplomatic, military, and domestic operations in support of national, continental, and international requirements including OP FRICTION, OP SHARP GUARD, OP RECUPERATION, OP AUGMENTATION, OP MERCATOR, OP DETERMINATION, OP PERSISTENCE, OP PEREGRINE, OP TOUCAN, OP APOLLO, and OP ALTAIR.

[30] Naval forces are an excellent political military option as they can rapidly deploy, remain in theatre without complex logistic support, flexibly change roles in situ, are a symbolic representation of a state's interest / concern and, unlike armies, can easily put or extricate themselves in/from harm's way with ease. Peter T Haydon, *Sea Power and Maritime Strategy in the 21st Century: A "Medium" Power Perspective*, Maritime Security Occasional Paper No. 10 (Halifax: Centre for Foreign Policy Studies, Dalhousie University, 2000), 38.

Maritime Picture (RMP) in terms of surveillance and action has force multiplied the value of a Canadian naval diplomatic contribution.[31]

All of these spheres, domestic, continental, and international, have a common link in that they require the Navy to be able to effectively conduct and appropriately disseminate reconnaissance and surveillance information to the greatest extent possible and to a wide range of 'customers.' This is where naval aviation, and in particular TUAVs, can be an effective contributor.

Section 3: Maritime Aviation Roles

As expressed in both Leadmark and Strategy 2020, DND and the CF have been given entrusted with the mission "To defend Canada and Canadian interests and values while contributing to international peace and security."[32] The development of an effective force structure to accomplish this mission requires an understanding of the spectrum of conflict. This spectrum is well presented in the following Figure taken from Leadmark and served as the basis for the creation of the force planning scenarios at Table 1.

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[31] This was most recently exemplified when Canada was assigned Command of an international coalition Task Force during OP APOLLO in order to conduct interdiction operations.

[32] Department of National Defence, *Leadmark: The Navy's Strategy for 2020* (Ottawa: DND Canada, 2001), 9.

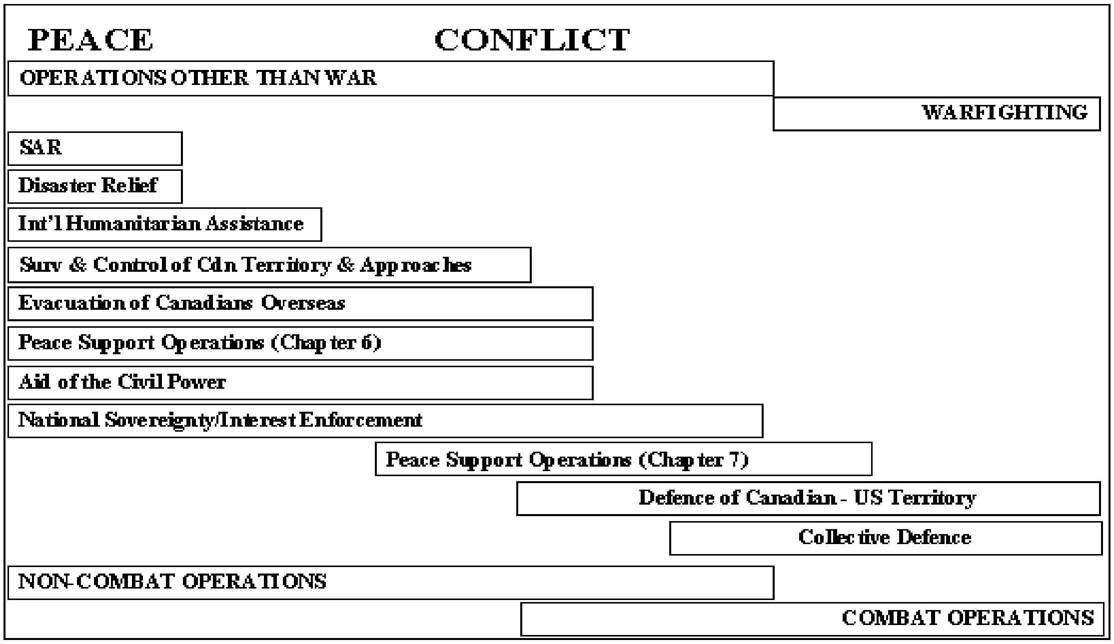

Figure 2. Spectrum of Conflict.[33]

The force-planning scenarios span the spectrum of conflict and provide guidance to the CF for development of an effective force structure to meet its mission. Leadmark also identifies "Versatile and combat capable" as a principle of medium power naval strategy.[34] This principle affirms that while, "naval forces structured to undertake mid-level combat operations have the capability to perform the constabulary role, the reverse does not hold."[35] Thus, if CF maintains a force structure that can meet the demands of Combat Operations at the full right of Figure 2, then it will be able to support national requirements across the spectrum. A review of the force-planning scenarios from a maritime aviation perspective will illustrate how organic aviation plays a crucial role in the Navy.

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[33] Department of National Defence, *Leadmark: The Navy's Strategy for 2020* (Ottawa: DND Canada, 2001), 16.

[34] *Ibid*, 46.

[35] *Ibid*, 47.

Ship borne naval aviation initially grew out of a need to conduct tactical reconnaissance and was affected by catapult launched seaplanes onboard battleship and cruiser class combatants. While tactical surveillance is still a vital function of naval aviation, it is but one of many roles. Adding the Leadmark Navy roles to the force planning scenarios at Table 1, a new table has been created to indicate how naval aviation contributes to operations. Putting context to Table 3, naval aviation force multiplies a warship's capabilities. For example, naval aviation increases surveillance coverage of its parent ship by over 25 times,[36] augments its SAR range (a helicopter can transit over 100nm from the ship to save personnel from a distressed vessel), and permits targeting and engagement of hostile forces at long range with ship-based weapon systems.

Force Planning Scenarios	Leadmark Navy Role	Naval Aviation Contribution
1. Search and Rescue in Canada	Constabulary	▪ Search Surveillance ▪ Communications Relay ▪ Helicopter Delivery Service and Personnel Evacuation
2. Disaster Relief in Canada	Constabulary	▪ Surface Search Surveillance ▪ Communications Relay ▪ Helicopter Delivery Service and Personnel Evacuation
3. International Humanitarian Assistance	Diplomatic	▪ Surface Search Surveillance ▪ Helicopter Delivery Service and Personnel Evacuation
4. Surveillance / Control of Canadian Territory and Approaches	Constabulary	▪ Surface Search Surveillance
5. Protection and Evacuation of Canadians Overseas	Diplomatic	▪ Surface Search Surveillance ▪ Personnel Evacuation

[36] Organic air assets significantly increase the tactical communications horizon and can cover more than 25 times the area of a warship alone. "The radar range is calculated using the formula: Radar Range = 1.23 x the square root of the Altitude of the radar. A HALIFAX class will have radar coverage of approximately 740 sq. nm/hr at a cruise speed of 12 kts. At a 2,000 ft altitude, the MH will have a radar coverage of approximately 20,000 sq. nm/hr at a cruise speed of 120 knots." Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 1/47.

6. Peace Support Operations (Chapter 6)	Diplomatic / Military	▪ Surface Search Surveillance ▪ Tactical Communications Relay ▪ Naval Boarding Party Support ▪ Helicopter Delivery Service to ship and littoral land forces
7. Aid of the Civil Power	Constabulary	▪ Surface Search Surveillance ▪ Helicopter Delivery Service
8. National Sovereignty / Interests Enforcement	Constabulary	▪ Surface Search Surveillance ▪ Tactical Communications Relay ▪ Naval Boarding, DFO, RCMP, CEC Party Support
9. Peace Support Operations (Chapter 7)	Diplomatic / Constabulary/ Military	▪ Surface Search Surveillance ▪ Tactical Communications Relay ▪ Naval Boarding Party Support ▪ Combat Operations Support (e.g. ASW &ASuW Search, Targeting, Attack, and Battle Damage Assessment) ▪ Helicopter Delivery Service to ship and littoral land forces
10. Defence of Canada/US Territory	Diplomatic / Military	▪ Surface Search Surveillance ▪ Tactical Communications Relay ▪ Combat Operations Support (e.g. ASW & ASuW Search, Targeting, Attack, and Battle Damage Assessment) ▪ Helicopter Delivery Service to ship and littoral land forces
11. Collective Defence	Diplomatic / Military	▪ Surface Search Surveillance ▪ Tactical Communications Relay ▪ Combat Operations Support (e.g. ASW & ASuW Search, Targeting, Attack, and Battle Damage Assessment) ▪ Helicopter Delivery Service

		to ship and littoral land forces ▪ Littoral Intelligence Collection

Table 3. CF Organic Naval Aviation Roles

While Table 2 provides only a basic summary of the main roles and is not all inclusive, it effectively demonstrates that naval aviation is a very positive contributor in all the developed force planning scenarios and Leadmark naval roles, and in all the domestic, continental, and international spheres.

Section 4: Roles – Conclusion

The maritime environment is a strategically complex and vital one for Canada. As a result, the CF requires a force composition that can meet the challenges across the spectrum of conflict. The essence of this spectrum has been articulated within the force planning scenarios which in turn permit important decisions to be made about what force structure the CF requires. From a maritime perspective, naval aviation contributes very effectively across the spectrum of conflict and is a true force multiplier. The next chapter will examine the MH SOR and TUAV capabilities to evaluate how effectively the 'Next Navy'[37] can meet its naval aviation needs.

[37] "The Next Navy – is being designed and built to exist within the window from five to approximately fifteen years (Horizon 2). The Next Navy planning process is concentrated on the development of a program that will realize a modernized navy, within imposed policy and resource constraints. Department of National Defence, *Leadmark: The Navy's Strategy for 2020*, (Ottawa: DND Canada, 2001), 22.

Chapter 4

Capabilities & Missions

Section 1: Introduction

While Maritime Helicopters and TUAVs have many similar capabilities, they are also fundamentally different aircraft. They each have strengths and weaknesses in terms of design, logistical support, and performance characteristics. This chapter will discuss the capabilities that are resident in MHs and TUAVs and then compare how well they meet the Navy's requirements.

Section 2: MH – Capabilities

In satisfying the MH SOR, the MH that will replace the CH124A will bring with it the capability to meet the roles currently supported by the Sea King. In terms of the scope of this paper and current procurement processes with the DND, it is assumed that the introduction of a TUAV capability within the Navy would not happen before the arrival of the replacement MH. Therefore, for illustrative purposes the MH SOR will serve as the measure against which TUAV capabilities will be contrasted.

Since the Canadian Navy's incorporation of maritime helicopters in its major warships in 1967, CF naval force structure has maintained a core naval helicopter capability. The MH SOR was constructed considering the requirements of the 1994 Defence White paper, the Defence Planning Guidance and the Canadian Joint Task List,[38] and it clearly established the MH capability requirements for a multi-purpose, combat

[38] Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 4/47.

capable MH. The MH SOR has taken into account the Force Planning Scenarios that the CF could be called upon to perform and has outlined the tasks that the MH will be able to perform in terms of Surface Surveillance and Control, Subsurface Surveillance and Control, and Utility Operations.[39] In sum, it is assessed that the MH replacement will be able to support the Navy in Defending Canada, Defending North America, and Contributing to International Security. In meeting the MH SOR, the replacement MH will be flexible, capable, and able to support the necessary range of missions.

Section 3 MH – Concept of Operations

On reviewing the MH SOR, one is struck by how "Sea King-like" the MH replacement will be. Certainly it will bring new generation technology to this vital asset but in the main there are no exceptional departures from current Sea King maritime air operations. Crew composition, basic toolbox capabilities, and mission / scenarios / roles are comparable to how Sea King operations are conducted today. The new MH will, for all intent and purpose, operate and have the capabilities of the Sea King but will be stronger, better, and faster.

Section 4 MH – Concept of Support

In terms of support, training and technology, the next MH will likely have the advantages of modern helicopter design. It will have better serviceability rates, growth capability provided for to a limited extent,[40] and very good performance / technological

[39] *Ibid,* 2/47.

[40] The MH SOR stipulates that a requirement for 10% 'growth' factor will be built in over the life of the aircraft. This is assessed to be a limiting factor as the MH SOR also states that the Sea King required

characteristics.[41] Importantly, the MH SOR envisages minor adaptations to current ship design (relative to the scale of effort), use of existing base/ship support infrastructure, and support doctrine that is consistent with how the Sea King is sustained.[42] In plain terms, the MH SOR sets the scene to replace the Sea King with an easy to introduce, capable platform that will perform the same essential functions as its predecessor only more cheaply, effectively, and reliably. Thus, the MH replacement will be able to satisfy the roles outlined in Leadmark and those required in the force planning scenarios.

Section 5: TUAV - Introduction

TUAVs are not the panacea of organic maritime assets. While they cannot do all the maritime roles and tasks that MHs can, there are those that TUAVs are better suited to than a MH and there are a number now that they can do that an MH cannot or would not be tasked to do. This important issue will be examined later in this chapter. While many countries have employed UAVs in support of land operations, the use of TUAVs in the maritime environment is a relatively new adaptation. Therefore, it is appropriate to introduce the three general characteristics of maritime TUAVs:

a. launch and recovery;
b. size, propulsion and endurance; and
c. payloads.

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a growth of approximately 30% over its service life. This will be an important benefit analysis point for MH and TUAVs. *Ibid*, 24/47.

[41] *Ibid*, 17/47, 19/47-20/47, and 37/47.

[42] *Ibid*, 19/47-20/47, and 26/47.

Section 6: TUAV – Launch and Recovery Methods

As pictured in Figure 4 below, maritime tactical TUAV design for frigate and destroyer sized warships has generally two broad groups, Vertical Take-Off and Landing (VTOL), and rocket launch and net (e.g. Pioneer) or marine recovery. In the VTOL category, there are subgroups, rotary wing (e.g. Fire Scout and Dragon Warrior) and rotary-to-forward-flight transition (e.g. Eagle Eye). The net recovery method runs an increased risk of damage to the vehicle and is optimally suited for larger decks.

Figure 3. TUAV Variants.[43]

Each of these design types has distinct advantages. With the ability to launch and recover from destroyer and frigate-sized flight decks, VTOL variants offer flexibility and survivability at generally the expense of payload capacity, speed, and endurance. Rocket launch and net/marine recovery systems have the opposite characteristics plus a

[43] United States. Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 7-13.

serviceability penalty over the long term.[44] It is important to note that VTOL systems are just now beginning to prove reliability in marine conditions from small flight decks. Advances in VTOL system design and functionality, including automated launch and recovery systems evidenced in the Integrated Deepwater Project (Eagle Eye) and DoD UAV programs (Fire Scout), are maturing quickly.

Section 7: TUAV – Size, Propulsion, and Endurance

There is no standard or widely accepted TUAV design. Consequently, existing models and prototypes range widely in size, propulsion, and shape and can weigh empty anywhere from hundreds to over 2000 lbs. Generally, TUAV endurance figures vary from 1.5 – 5 hours though longer endurance TUAV types (the A160 Hummingbird may offer up to 24 hour endurance) are emerging. Propulsion technology is arguably the most difficult TUAV design feature to reconcile. Two stroke engines offer excellent power-to-weight ratios but poor efficiency. Four stroke engines are better but at the cost of increased weight. The marine operating environment and the desire to use heavier JP and/or diesel fuels to take advantage of existing maritime fuel sources further complicates this tough choice. Finally, there is an appreciable development risk and expense that must be factored into the propulsion equation when considering designing a TUAV-specific engine vice attempting to integrate a commercial off-the-shelf engine (which is not designed and optimally suited for TUAVs and/or the maritime environment).[45]

[44] E.R. Hooton, "Maritime Drones – Back to the Future?" ***armada*** *International* (1/2004): 61-62.

[45] *Ibid*, 76.

As previously mentioned, TUAVs come in many shapes and sizes. For illustrative purposes, the U.S. TUAVs in Figure 3 and Table 4 serve as generic examples of the scope of existing TUAVs.

	Fire Scout	Dragon Warrior	Pioneer	Dragon Fly*	Eagle Eye

Section 8: TUAV – Payloads

As depicted in Table 5, the US military has budged considerable R&D funding (over $16 billion USD over 7 years, $492 million for the Fire Scout TUAV alone) into UAV programs to develop this capability.

Program	FY03*	FY04*	FY05*	FY06*	FY07*	FY08*	FY09*	Total*
Predator	227.9	358.0	329.4	355.0	241.4	266.5	374.2	2152.4
Pioneer	29.1	36.3	17.7	9.9	10.7	11.2	11.4	126.3
Hunter	33.9	29.2	28.2	28.1	26.0	24.6	25.2	195.2
Global Hawk	510.5	624.2	625.7	688.8	869.6	800.5	730.6	4849.9
Shadow 200	179.0	132.0	124.8	89.0	90.5	93.6	90.2	799.1
ER/MP	0.0	23.1	33.6	71.0	85.7	140.0	168.7	522.1
Fire Scout/VTUAV	38.6	4.0	0.0	0.0	0.0	180.0	270.0	492.6
UCAV (AF & Navy)	171.3	347.8	573.3	530.3	361.7	914.7	1226.1	4125.2
BAMS	0.0	25.1	224.4	187.1	322.1	415.2	440.3	1614.2
GH Maritime Demo	189.4	76.4	57.3	59.2	61.9	56.5	56.9	557.6
UCAR	33.0	49.4	75.9	107.7	84.2	86.2	47.0	483.4
Various Small UAV	51.6	52.4	55.0	55.0	55.0	55.0	55.0	379.0 estimated
Grand Total	**1455.7**	**1761.6**	**2139.1**	**2158.0**	**2199.6**	**3016.9**	**3459.5**	**16190.4**

* All budget figures are given in millions of dollars and roll up RDT&E, procurement, and O&S together.

Table 5. US DoD FY 04 Presidential Budget for UAV Programs[49]

This level of investment and commitment will serve to create advances in all areas of UAVs/TUAVs and perhaps most significantly in the area of payload capabilities, which is arguably an already highly developed TUAV technology. That said, the commercial sector and physics are still the driving factors and/or limiters. As pointed out in the UAV Roadmap 2002 Technologies section, "Moore's Law states the number of transistors on a microprocessor will double every 12-18 months, enabling a corresponding increase in computing power."[50] Therefore, considering the speed of advance of microprocessor technology and the limit of silicon technology in the 10 THz range, there is room to grow but not unlimited potential. Therefore, scientific advances will further reduce payload weight and/or improve onboard processing and capability without a corresponding endurance penalty. In terms of the life cycle cost of a CF TUAV system acquisition,

[49] Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 20.

[50] *Ibid*, 41.

technology will also offer the ability to plug and play the next generation of payload sensors without prohibitive costs of an engineering modification to a manned aircraft.[51] Figure 4 puts the cost, payload, and endurance triad into perspective: increased payload size demands a correspondingly larger TUAV, which in turn costs more. Maritime TUAVs have generally a 100-300 pound payload, 3-5 hours of endurance, and cost between $500,000 - $1,000,000 USD. Larger TUAVs such as the Fire Scout effectively balance cost and capability. Maritime aviation costs will be examined in greater detail in Chapter 6.

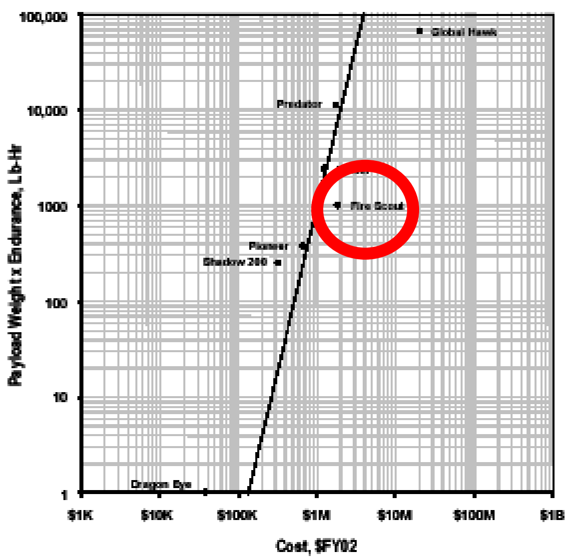

Figure 4. UAV Performance Metric: Endurance v. Cost[52]

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[51] Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 24/47.

[52] ISR stands for Intelligence Surveillance and Reconnaissance. United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 33.

Section 8.1: TUAV – Payloads – Sensors

It is likely that the sensor suite selection will represent a challenging capability choice when acquiring a TUAV as “Sensors are increasingly becoming the pacing item for the cost of unmanned vehicles dedicated to ISR.”[53] The developed sensor options for TUAV payloads are numerous and include Electro Optic (EO), Infra Red (IR), Nuclear Biological Chemical (NBC) detection, Synthetic Aperture Radar/radar, Signal Intercept (SIGINT), and Wet Film.

Current generation EO systems such as those depicted at Figure 5 are capable of NIIRS 6.5 at nadir and NIIRS 4-5 in IR at close range.[54] This capability would greatly enhance the Navy’s ability to covertly track and investigate targets of interest and ranges outside counter detection. On the technological horizon, Multispectral and Hyperspectral Imagery (MSI/HSI) promise a magnitude increase in imagery quality as well as remote chemical or biological detection. Further, Foliage Penetration and Light Detection and Ranging may to solve the “target under tree” (or in a maritime context the ‘foggy day’) surveillance problem.[55]

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[53] *Ibid,* 87.

[54] NIIRS is the National Image Interpretability Rating Scales. “The aerial imaging community utilizes the NIIRS to define and measure the quality of images and performance of imaging systems. Through a process referred to as “rating” an image, the NIIRS is used by imagery analysts to assign a number which indicates the interpretability of a given image.” For example, EO NIIRS 6 would be able to distinguish between small / medium helicopters (e.g. Helix A helicopter from a Helix B) and IR NIIRS 5 would be able to identify the smoke stack shape (e.g. square, round, oval) on large merchant ships (e.g. greater than 20099197 154.79997 Tm(t51.02 0 0 10.02 370.T262.7052r(e m)Tj10.02 0 0 1)0 0 10.02 370.T262.7058.6 0 79997 T

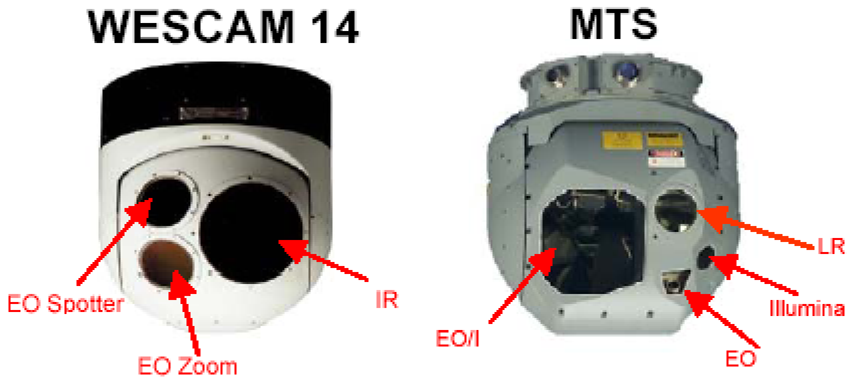

Figure 5. UAV EO/IR Payload[56]

Recent advances in radar technology (both weight/size reduction and capability) have enabled UAVs and TUAVs to take over crucial surveillance and reconnaissance roles from manned aircraft. Existing synthetic aperture radar systems such as the one at Figure 6 are light enough to be employed in many existing TUAV variants and offer excellent detection and resolution characteristics.[57] Significant synthetic aperture radar advances are currently limited by TUAV onboard processing capacity and/or downlink bandwidth for ground station processing. Able to perform limited coherent change detection,[58] significant developments are likely by the end of the decade for larger MALE/HALE UAVs but not for TUAV size vehicles.[59]

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[56] *Ibid*, 180.

[57] The IAI/Elta EL/M-2055D Synthetic Aperture radar (SAR) weighs only 35-40kg and, "Equipped with this compact SAR, a tactical UAV can cover 1,000 square kilometres per hour, with a medium resolution images, or get high resolution spot views or Ground Moving Target Indication (GMTI) from distances of 100 km and beyond." available from http://www.airshow.mod.gov.il/news_article_5.htm; Internet; accessed 15 March 2004.

[58] MTI is moving target indicator and refers to a radar's ability to display only moving vehicles and not terrain or dense clouds. This feature is very useful when conducting surveillance and reconnaissance operations.

[59] United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 91.

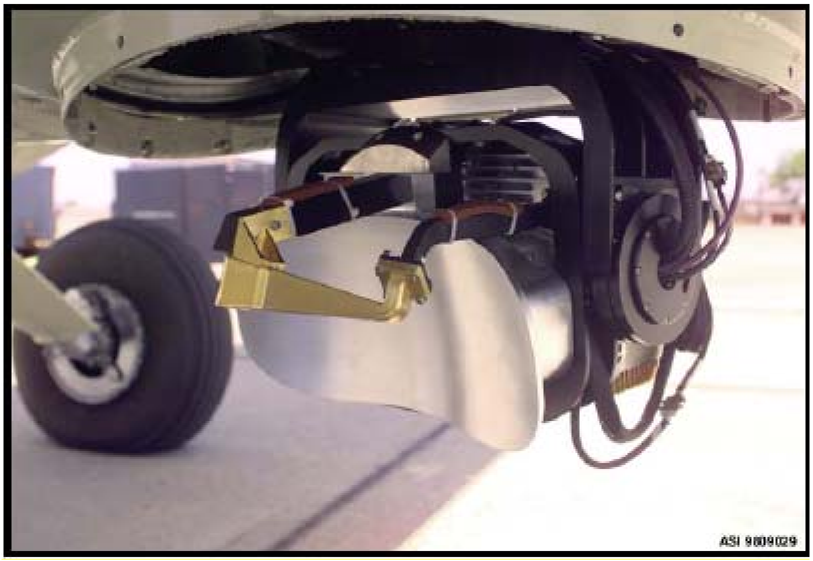

Figure 6. UAV SAR with GMTI

As UAV use expands to more and more militaries (and commercial viability increases as well) other capabilities will begin to emerge and be developed. Already developed or in the final stages of development, it is predictable that meteorological data monitoring (weather and gunnery forecasting), NBC detection and classification, and electronic warfare target motion analysis and/or cross fixing will form core TUAV capabilities.[60] Incremental capability growth is a major benefit of TUAVs over manned aircraft, which are traditionally "difficult and expensive when the weapon system is unable to accommodate growth. Failure to anticipate the 'growth' factor in the procurement of the weapon system can lead to extremely costly upgrades or premature obsolescence."[61] TUAVs will be able to exploit in a relatively simple fashion the

[60] Such as Titan Systems' FinderPlus and Story Finder electronic support measures systems. *Janes International Defense Review*, "Lightweight ESM fit promoted for UAVs," Vol 37, Issue 3, (March 2004): 29.

[61] Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 24/47.

emerging generations of Electro Optic, NBC detection, Signal Intercept etc (e.g. either through acquisition, leasing, or mission related lease etc) sensors that would be prohibitively difficult to incorporate into manned MHs due to the significant study, engineering effort, and costs.[62] Overall, in considering the TUAV sensor capabilities, it is important to emphasize that existing and Horizon 2 TUAV technologies can meet the needs of the Navy of Today and the Next Navy.[63]

Section 8.2: TUAV – Payloads – Communications

There are current Medium Altitude Long Endurance (MALE)/High Altitude Long Endurance (HALE) UAV (such as Predator) designs that have the capability to be controlled beyond line of sight and TUAV/MALE/HALE variants that are able to automatically relay VHF and UHF radio and voice communications. This is an important emerging technology that may serve to support the CF when satellite communication services are interrupted and/or are unavailable. It is foreseeable that this capability could prove vital to many of the constabulary and diplomatic roles (e.g. Search and Rescue operations in a ravine or remote bay) that the Navy will be called upon to support.[64]

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[62] While systems of this nature have existed for some time, it was never assessed as cost effective to upgrade the Sea King with these important capabilities. Further, their inclusion in the initial EH 101 design rendered that initial MH replacement as prohibitively expensive resulting in it becoming an election issue in 1993 and subsequently being cut. Finally, the Aurora modernization program is a poignant and expensive example of the level of engineering effort and time it takes to modernize a sophisticated military aircraft.

[63] Department of National Defence, *Leadmark: The Navy's Strategy for 2020*, (Ottawa: DND Canada, 2001), 22 and 23.

[64] By their nature, many FPSs involve a mix of military, OGD, NGO, and civilian resources and could be located remotely or in regions that are not serviced by satellite resources. Therefore, TUAV communications relay may provide an excellent bridging/enabling technology (e.g. Search and Rescue in Canada, Disaster Relief in Canada, International Humanitarian Assistance, Protection and Evacuation of Canadians Overseas, and Aid of the Civil Power).

Section 9: TUAVs and MHs – Complementary Missions, Scenarios, and Roles

As mentioned previously, the MH replacement will be able to adequately support the three naval roles expressed in Leadmark. The preceding sections highlighted the potential of TUAVs and at this juncture, it is appropriate to compare the complementary capabilities that are resident in MHs and TUAVs. Table 6 expands Table 3 from Chapter 3 and presents the assessed maritime roles and missions that TUAVs and MHs can accomplish. While Table 6 does not list exhaustively the roles and missions that naval aviation can be called upon to support, it offers a concise maritime focused cross-section that is firmly linked to the force planning scenarios.

FPS	Leadmark Navy Role	Naval Aviation Contribution	MH Supported	TUAV Supported
1. Search and Rescue in Canada	Constabulary	▪ Surface Search Surveillance ▪ Communications Relay ▪ Helicopter Delivery rvH(uni)Tj10.02		

6. Peace Support Operations (Chapter 6)	Diplomatic	▪ Intelligence, Surveillance, and Reconnaissance ▪ Tactical Communications Relay ▪ Naval Boarding Party Support ▪ Helicopter Delivery Service (HDS) to ship and littoral land forces	x Note 1 x Note 4	x x Note 3
7. Aid of the Civil Power	Constabulary	▪ Surface Search Surveillance ▪ Helicopter Delivery Service (HDS)	x x	x
8. National Sovereignty / Interests Enforcement	Constabulary	▪ Surface Search Surveillance ▪ Tactical Communications Relay ▪ Naval Boarding, DFO, RCMP, CIC Party Support	x Note 1 x	x x Note 3
9. Peace Support Operations (Chapter 7)	Diplomatic / Constabulary/ Military	▪ Intelligence, Surveillance, and Reconnaissance ▪ Tactical Communications Relay ▪ Naval Boarding Party Support ▪ Combat Operations Support (e.g. ASW & ASuW Search, Targeting, Attack, and Battle Damage Assessment) ▪ Helicopter Delivery Service (HDS) to ship and littoral land forces	x Note 1 x x Note 4	x x Note 3 Note 5
10. Defence of Canada/US Territory	Diplomatic / Military	▪ Intelligence, Surveillance, and Reconnaissance ▪ Tactical Communications Relay ▪ Combat Operations Support (e.g. ASW & ASuW Search, Targeting, Attack, and Battle Damage Assessment) ▪ Helicopter Delivery Service (HDS) to ship and littoral land forces	x Note 1 x Note 2	x x Note 5
11. Collective Defence	Diplomatic / Military	▪ Intelligence, Surveillance, and Reconnaissance ▪ Tactical Communications Relay ▪ Combat Operations Support (e.g. ASW & ASuW Search, Targeting, Attack. and Battle	x Note 1 x	x x x

		Damage Assessment) ▪ Helicopter Delivery Service (HDS) to ship and littoral land forces ▪ Littoral Intelligence Collection	Note 4 Note 2	 x

Table 6. CF Organic Naval Aviation Roles and the MH & TUAV.

Note 1: The MH will be able to support manual relay of voice information. TUAV's have the capability to auto-relay voice and data information.
Note 2: An MH's ability to support littoral intelligence collection would be constrained by the assessed stand-off range (and the associated risk level) in force and the capability of original fitted and embarked sensors. In contrast, and unmanned TUAV would be able to be more aggressively employed in a high-risk environment with state-of-the-art sensors optimized for intelligence collection.
Note 3: TUAV support to NBP and OGD boarding parties would be limited to search, surveillance, and monitoring of boarding operations, evidence gathering and auto communications relay. In contrast, an MH would be able to additionally provide the TUAV (less auto-relay communications and video feed) capabilities plus an effective operational presence and limited direct combat support to boarding operations.
Note 4: MH support littoral to land forces would be restricted to a benign environment given MH design limitations.
Note 5: TUAVs are not assessed as having an ASW capability in the Horizon 2 timeframe.[65]

In reviewing Table 6, a number of issues concerning the ability of TUAVs to meet the Navy's requirements can be noted. First, while it may be possible to conduct limited helicopter delivery service missions with TUAVs, the practical restrictions in terms of payload capacity, ease of transfer etc. make this mission unlikely in the near term. Therefore, the MH is an essential capability for the Navy as many force planning scenario missions require a helicopter delivery capability. Revolution in Military Affairs literature has highlighted that unmanned logistics aircraft are in development however in view of the Navy's requirements and the MH replacement's anticipated capabilities, this is not assessed as a vital avenue to pursue.[66] Second, TUAVs can support naval boarding and OGD party operations in a surveillance and monitoring role but not in a presence and/or combat support role. It is notable that the MH is also very restricted in its ability

[65] Stephan Nitschke, "Unmanned Aerial Vehicles – What do Navies Really Need?" *Naval Forces* Vol 24, Issue 6 (2003): 26.

[66] John McCoy, "Unmanned Aerial Logistics Vehicles – A Concept Worth Pursuing," *Army Logistician* Vol 36 Issue 2, (March/April 2004): 40.

to provide effective defensive support to boarding teams. Third, in an ASW threat environment, MHs are essential as TUAVs do not currently have this capability. Fourth, given existing surveillance capabilities, it is assessed that TUAVs can satisfy the Navy's intelligence, surveillance, and reconnaissance requirements. Further, cooperative employment of TUAVs and helicopters would appreciably increase the Navy's overall flexibility, redundancy, and effectiveness. TUAVs will also improve MH efficiency and effectiveness by acting as a queuing platform.[67] Fifth, the ability of TUAVs to automatically relay tactical communications and data is a significant advantage over what the MH will be able to do. This will quicken the decision cycle in constabulary and time-sensitive military operations, enhancing effectiveness. The ability to tailor TUAV payloads (e.g. Signal Intercept, wet film, Electro Optic/Infra Red etc.) to the mission will also have a positive impact. It will ensure that the desired capability set is in place when needed and will enhance data/intelligence collection. Further, the ability to tailor payloads and automatically relay information to multiple sources has promising joint potential, creating a firm link between the Army and Navy in operations.[68] Finally and arguably most importantly, TUAVs can be employed in higher risk roles than might be acceptable/prudent for manned MHs. Their small size, manoeuvrability, advanced sensor suite, relatively low cost, and ability to provide near real-time information directly to

[67] For example, in a SAR scenario, TUAV(s) would conduct the search task, finding the distressed vessel such that the MH could launch proceed directly and maximize time conducing SAR operations. Situation dependant, an alternative would be to launch both the TUAV and the MH to double the surveillance effort and find the distressed vessel that much more quickly.

[68] The ability of the Navy and Army to jointly employ TUAVs in support of RMP and situational awareness would have been of great benefit during littoral operations in East Timor and Somalia (and Haiti should the Navy become involved). The Pioneer TUAV provided this function for the U.S. Marines, Army and the Navy during DESERT STORM in 1991.

Command for operational and/or tactical decision or dissemination make TUAV employment in support of high-risk (especially littoral) operations optimal.

Section 10: TUAV & MH – Conclusion

In supporting this paper's assertion that TUAVs are an essential maritime aviation complement to maritime helicopters (MH) within the Canadian Navy, this chapter has enriched the discussion to include the capabilities of the MH replacement and TUAVs. In short, the MH will be very 'Sea King-like' and bring with it a very capable but traditional capability set. This is also a drawback in that the MH will not introduce any new capabilities and will only have modest growth factor over the life of the asset. Thus the MH is not optimally suited to support the changing nature of Navy operations, which will include increased United Nations Chapter 7 operations, national security operations, and increasing OGD support. The planned acquisition of the Joint Support Ship is yet another signal that CF is moving in a new and dynamic direction that can be best supported by a flexible asset that can grow and the nature of warfare changes.

Flexibility is a TUAV strength, both in operations and over its lifecycle. The unmanned TUAV (and the associated payload) can be mission tailored from a wide range of sensor options such that it can be employed in high-risk operations and in support of standard but essential surveillance roles. Employed in this fashion, TUAVs will be an ideal complement to the MH. Further, though the MH has a modest 10% growth factor over the life of the airframe as a design requirement,[69] TUAVs offer an order of magnitude improvement in growth and adaptability. As a MH – TUAV team, this offers

[69] Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 24/47.

the long-term option to not force a design change on the MH to acquire an emerging and/or important capability (e.g. Signal Intercept) and the short-term flexibility to ensure that the ship or TG has at its disposal the right capability set to accomplish the mission at hand. Costs and capabilities aside for a moment, it is important to fully appreciate what an unmanned aircraft can offer in high-risk operations. Whether it is marginal sea conditions in a search and rescue or the conduct of a military targeting and missile engagement, TUAVs offer their capability at no risk to human life.

As an overall conclusion, TUAVs can support operations in all roles, force planning scenarios, and missions. Its unique capability set and ability to be task tailored make the TUAV a better platform than the MH in a wide variety of situations. That said, TUAVs cannot replace maritime helicopters. There are times when radar and infra red information is not enough and then a manned aviation asset will trump TUAVs in terms of gaining a full 'eyes-on-the-target' appreciation of a situation[70] (plus the advantage of local situational awareness and a 360^{o} field of view for a manned aircraft versus $2\text{-}7^{o}$ for a TUAV).[71] Further, there are essential functions that an MH can fulfil that TUAVs simply cannot (e.g. helicopter delivery service, ASW). Fundamentally, the two assets have very complementary capabilities that together force-multiply the Navy's use of maritime aviation.

[70] Richard K. Harrison, "TacAir Trumps UAVs in Iraq," *Proceedings of the United States Naval Institute* Vol 129, Issue 11 (November 2003): 58.

[71] Rear Admiral Michael "Carlos" Johnson, US. Navy (Retired), "End Manned Aerial Reconnaissance," *Proceedings of the United States Naval Institute* Vol 130, Issue 4 (Apr 2004): 20-22.

Chapter 5

TUAV Integration

Section 1: TUAV – Introduction

It is perhaps tempting to think that there are simply too many difficult issues involved with integrating TUAVs into the CF and the maritime environment. While introducing leading edge technology is challenging, TUAV integration into the CF is viable. This chapter will first examine equipment and personnel challenges to assert that the addition of TUAVs within the existing infrastructure is entirely feasible. It will then highlight the operational capabilities that TUAVs bring to the fight to show why they are worth the effort.

Section 2: TUAV – Maritime Air Group and Navy

It is appropriate to consider first whether organic maritime TUAVs should be Naval or Air Force assets. Should Tactical Unmanned Aerial Vehicles be Air Force assets that are operated by Air Force personnel much as MHs have been? On deeper reflection, there are important reasons why this is mainly but not entirely the case.

The first point that intuitively favours TUAVs as an Air Force Asset is the Maritime Air Group (MAG). MAG is an Air Force group that has been in the Navy family for decades. As a result, MAG understands naval aviation and, more importantly, understands what the Navy needs from its organic air assets. Next, the Air Force has the core skill sets to fly, operate, and maintain TUAVs and those that are not resident can be quickly assimilated. Finally, TUAVs are an aviation asset. It is assessed that the Air

Force is best suited to undertake this capability initiative from a resource management, sustainment, flight safety, employment, and force generation point of view. However, from a Navy perspective and considering the technological advances expected in TUAV operational design, a blend of Air Force and Navy personnel (vice uniquely Air Force personnel) would likely best address crew composition. Air Force, Navy and Intelligence trade personnel all have varying levels of training in TUAV-like sensor operation and exploitation. Thus, it is assessed that while the Air Force is best positioned to undertake the TUAV capability initiative (just as they are maritime and tactical helicopters), there are options to meet TUAV crewing demands through a joint Air Force, Navy, and Intelligence branch approach to mitigate the personnel impact. These factors amongst others will be more fully developed in subsequent sections.

Section 3: TUAV – Operation and Support Issues – Equipment

TUAV Integration and Fleet Level of Effort. From a Navy perspective, the level of effort to integrate TUAVs is very dependant on the model of TUAV selected. In addition to the modest cabling, antenna, and GCS / PE terminal installations, modifications to the HHRSD and flight deck may be required to support (automatic) TUAV launch and recovery. Should a small TUAV model be selected, the impact on hangar housing (either deck head or bulk head) should be minimal. Larger TUAVs may not fit in the hanger with the MH and would therefore require an innovative approach such as a Bird Cage.[72]

[72] For example, a small storage structure could be mounted on the HALIFAX class quarterdeck just aft of the flight deck. Apart from a birdcage option, a TG level solution could be utilized (e.g. allocate individually TUAV and MH assets to ships as opposed to embarking both in the same ship).

infrastructure. Given the few TUAV systems that would be acquired, the anticipated MH fleet size and increase in hangar infrastructure, and the relatively small TUAV footprint, MAG shore facilities will be likely able to fully meet the requirement. Figure 8 from Bell promotional literature, shows the impressively small footprint of their Eagle Eye TUAV, which is one of the larger variants in development.

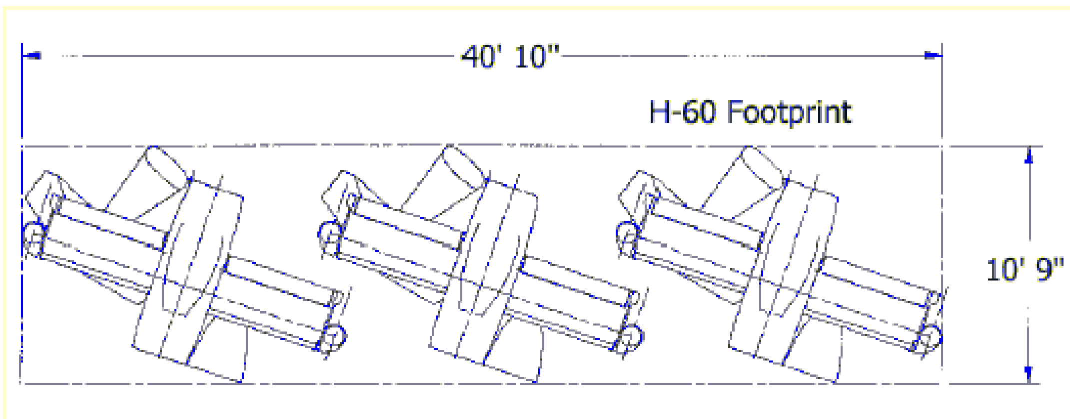

Figure 8. Eagle Eye footprint.[74]

TUAV System Components and Location. The general components that make up a TUAV system in an HMC Ship will include a Ground Control Station (GCS) terminal, Payload Exploitation (PE) terminal, recovery system, storage system, and the TUAV itself.

[74] Bell presentation information provided to the USCG as part of their Integrated DeepWater Project. As part of the USCG to the CF Experimentation Centre liaison, this presentation was forwarded to the CFEC for information and consideration.

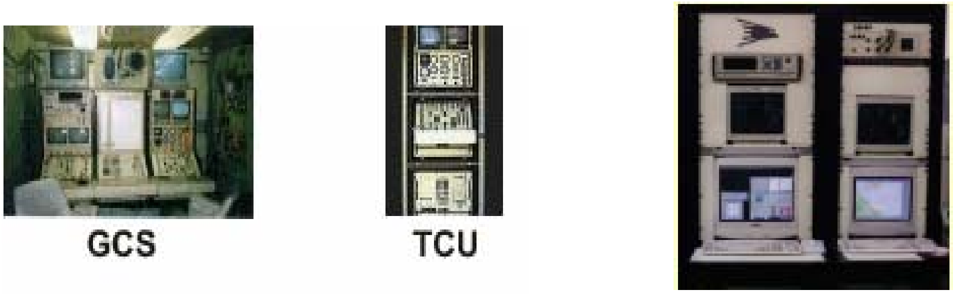

Figure 9. Pioneer and Eagle Eye GCS and TCU.

With regards to the GCS and PE terminals, it is desirable for these terminals to be located in or as near as practicable to the operations room. This will facilitate vehicle employment, payload sensor tasking, and payload information dissemination. The challenge to this objective is the relatively small space available in an operations room. Within the HALIFAX class operations room and to a markedly lesser extent the IROQUOIS' operations room, options exist to install a PE and / or GCS module.[75] If future HALIFAX/IROQUOIS design considerations make operations room installation impracticable then there a number of terminal location options in each class that balance proximity to the operations room and the intelligence team.[76] Finally, given the JSS' stage of development, it will be possible to incorporate TUAV GCS and PE terminal installation requirements into the design.

[75] In the HALIFAX class, the terminals could be located port side aft in place of the general workstation, centreline aft in place of the signalman's desk, and centreline aft in place of the chart table. In the IROQUOIS class, the staff office is an option but not desirable as it would significantly impact Command and staff activities.

[76]In the HALIFAX class, the GCS and/or PE terminals could be installed in the Combat Chief's office (aka OPS ADMIN), CCER 2, starboard side in place of the workstation and safe, and the CCER 1 forward starboard in place of the workstation. In the IROQUOIS class, CCERs 1 and 2 both provide quick access to the operations room and CDSE personnel.

Recovery and storage. Larger VTOL TUAV types such as the Eagle Eye and Fire Scout will likely employ automatic landing technology to bring the TUAV home and secured within a helicopter deck securing mechanism. Though beyond the scope of this paper, it is assessed as possible that the current Helicopter Hauldown system may be able to support TUAV requirements. For those TUAVs that do not use a trapping system, the flight deck will meet the requirement. Finally, fitted deck cranes of a HALIFAX and IROQUOIS class are capable of hoisting weights in excess of 2000lbs,[77] which is assessed to meet the requirements of a water entry and recovered TUAV. In terms of on board storage, options are available. Smaller TUAV variants could be effectively stored in the hanger with the MH. Alternately, larger TUAV variants could be stored on the upper decks forward of the hangar or in a Bird Cage on the quarterdeck.

Fuel. The fuels for existing TUAV designs include high-octane gasoline as well as JP 5 and JP8. Thus, options exist for the CF to select the TUAV propulsion system that best suits the Navy's infrastructure requirements. Considering the onboard tank arrangement and existing fuelling architecture within the HALIFAX and IROQUOIS classes (and anticipated arrangements within the JSS to support JP5 MH operations), it is more practical to employ a JP5 burning engine and take advantage of existing systems and procedures. As will be shown later in Table 8, TUAVs require approximately 1/5th or less fuel than MHs do for commensurate airborne endurance and operating radius. As such, current IROQUOIS and HALIFAX class JP5 fuel tank capacity is able to support TUAV and dual MH/TUAV operations.

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[77] The HALIFAX Class MIII-K2 deck cranes are tested in accordance with trials agenda C-28-470-000/NT-001. At their maximum reach of 26 ft, they are certified to 1800 lbs dynamic load (816 kg). At a reach of 20 ft, they are certified to 2200 lbs dynamic load (998 kg) and at a reach of 15 ft, they are certified to 2600 lbs dynamic load (1179 kg). Finally, the RHIB Davit is certified in accordance with C-28-400-000/NT-001 to 8250 lbs dynamic load (3742 kg).

Section 4: TUAV – Operation and Support Issues – Personnel

The crew composition in Navy warships has been carefully constructed to ensure that the ship is able to perform the full range of operations with the right balance of personnel skill sets. Further, this tight construct has been created with MH air detachment personnel and requirements in mind. Changes to this formula can result in holes appearing in the Watch and Station Bill[78] and risk induced when conducting operations. Therefore, the challenge of crewing a warship for deployed operations is about managing risk to maximize capability and personnel flexibility while supporting overall team and sub-team depth.[79] This section will examine the positions required for TUAV operations and then the personnel requirements of a TUAV detachment and a combined MH & TUAV detachment for local and DCDS deployed operations.

TUAV positions. Drawing on the experience of the U.S. Marine Corps in conducting Pioneer UAV operations, the following table is tailored to Canadian Navy requirements and describes the shipboard TUAV positions.

Position	OPI	Remarks
Mission Commander	ORO	Exercised by SWC and/or Snr NCIOP
Pilot	MH Pilot	Embark an additional MH pilot
Payload Operator	Cbt/CSE pers	Training akin to the Barracuda UCTS training model will afford shipboard flexibility. The option exists to incorporate this training into a Military Occupation though that would need to be part of a larger study.
Payload Analyst	Intel O, CDSE	If borne, the Intelligence Officer and embarked

[78] The Watch and Station Bill is the document/matrix that outlines where every HMC Ship sailor's duty station is for any given evolution from replenishment to full combat operations.

[79] Adding a Padre to the ship's company for a major deployment is a very positive move in terms of supporting ship's company morale. However, bringing a Padre means taking one less Bos'n, technician, or NCIOP.

	team, Cbt pers	CDSE team would be best positioned to exploit higher than tactical level analysis of TUAV sensor information. Ship's staff would be able to assess tactical level information (e.g. positional information, battle damage assessment) acquired by the TUAV for immediate use.
Maintenance Officer	AMO / Air CWO	In a JSS, it will be the Air Maintenance Officer and in an IROQUOIS or HALIFAX class it will be the Air Detachment CWO
Maintenance Team	Air Detachment	Allowing for efficiencies in scheduling, lower anticipated maintenance associated with the new MH and relatively low TUAV 1st and 2nd line maintenance requirements, it is assessed that the addition of two technicians will address and likely increase the level of MH air maintenance support.
Flight Deck Crew	Chapter 9 Organization[80] (re-named TUAV Deck Crew)	In considering operations beyond a 12-hour deck cycle, the additional MH pilot and 2 Maintenance technicians will meet the flight, maintenance, and fuelling requirements of TUAV operations but not the physical launch and recovery outside of the 12-hour MH deck cycle. (USCG Eagle Eye TUAV dets are comprised of two maintainer/launchers and two flyer/payload operators) Deck Crew and Firefighter limitations can be mitigated through the employment of a TUAV Deck Crew (existing Chapter 9 structure) drawn from shipboard staff. However, Firefighters and Hull Techs are also the backbone of the Chapter 9 team. Extension beyond a 12-hour deck cycle in support of TUAV operations can be met through the use of small numbers of cross-trained shipboard personnel. The incremental risk of using non firefighter or Hull Tech fire fighter trained personnel should be tempered by the anticipated automatic landing technology that is on the horizon and the relative size and weight of TUAVs (500-2000 lbs).

Table 7. TUAV Shipboard Detachment Positions.

[80] The Chapter 9 Organization is the ship board organization that is trained and capable of supporting limited air operations when an air detachment is not embarked. The ship can receive helicopters who land can land on deck without the aid of the landing system (HHRSD) to receive helicopter delivery service materials and to fuel to helicopter.

In sum, a combined MH and TUAV Air Detachment would require three additional personnel to permit beyond 12-hour deck cycle TUAV and MH operations. When HMCS VANCOUVER deployed for OP APOLLO, six mission-related personnel were embarked in support of the mission requirements (five were the intelligence team).[81] It is assessed as entirely feasible that an additional three billets can be offset to support TUAV requirements without the need of mission related bunking.[82] That said, bunking has been a persistent problem in the HALIFAX class and requires a detailed study to ameliorate crewing pressures.

[81] A one-in-four OOW rotation was maintained on the bridge.

[82] The author was the executive officer of HMCS VANCOUVER for the 2001 OP APOLLO deployment. The personnel challenges of incorporating a combined MH TUAV det under those circumstances are viewed as the "feasibility quality control line."

The following line diagram has been created to describe what a HALIFAX class combined TUAV and MH detachment in support of DCDS deployed operations could look like.

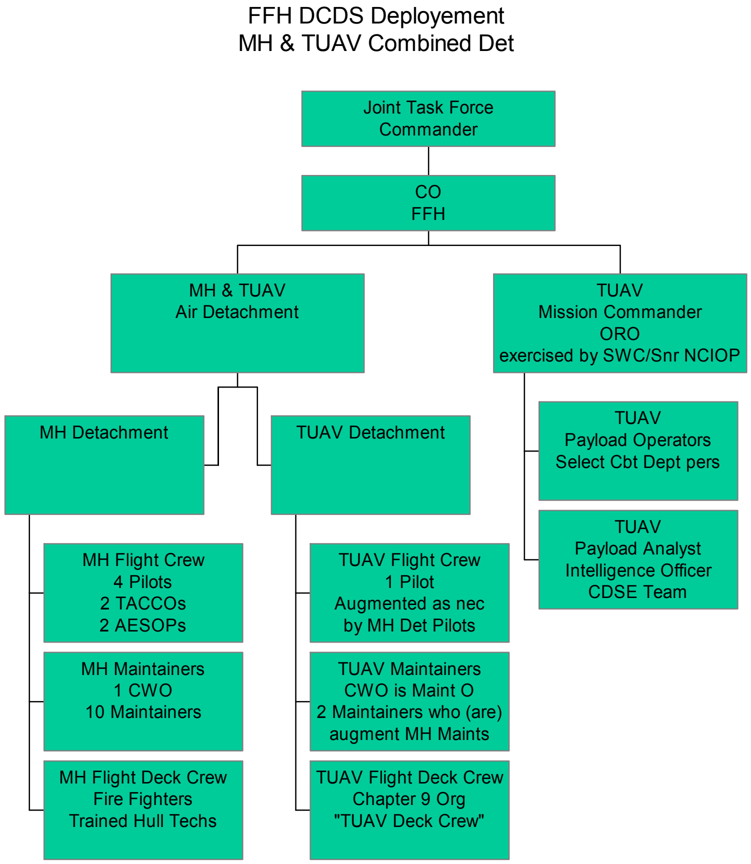

Figure 10. HALIFAX class DCDS Deployment MH & TUAV Combined Detachment.

It is appropriate to next examine who should pilot the TUAV. TUAV systems are operated from a remote location via radio link controls. The launch and recovery sequences will likely be automated[83] and in-flight route planning and execution will be a point-and-click process that could realistically be run by operations room personnel.

[83] The newer generation TUAVs such as Fire Scout and Eagle Eye employ automatic landing system technology.

However there are a number of reasons why an MH pilot is the best choice as the designated TUAV pilot and why that pilot should be an addition to the Air Detachment composition. First, notwithstanding possible automatic landing technology, factors such as weather (e.g. fog, building sea states etc.) and technology failure, require a trained person-in-the-loop to manage the risk. Second, FAA regulation permitting full TUAV integration into all airspace categories will be facilitated by the employment of a commercially rated pilot as the TUAV pilot.[84] The general difficulty of UAV integration into FAA airspace was poignantly evidenced during the PACIFIC LITTORAL experiment.[85] Third, studies on the effects of crew size and crew fatigue on the control of TUAVs concluded that reducing the number of operators increased fatigue and affected crew rotation resulting in 33% more aerial vehicle mishaps during emergencies, 13% increase in the time it takes to search for targets, and an 11% decrease in the number of targets detected.[86] These results support the need for a team of pilots vice the training and

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[84] FAA regulations have not yet matured to address TUAV operations. Given the manner in which military TUAVs will be operated, they will likely be recognized as aircraft, more specifically as remotely operated aircraft (ROA), and be regulated by the FAA. That said, the current parent regulation for full airspace usage would require a licensed pilot. United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 157.

[85] The experiment encountered significant challenges in reserving airspace for UAV operations and employed commercially licensed pilots alongside IAI's non-commercially rated pilots. Capt(N) K.D.W. Laing, *CFEC Experiment No. IISRA2003-1 – Pacific Littoral ISR Experiment Order* (Canadian Forces Experimentation Centre: file 3350-165/R (CFEC Experiment No. IISRA2003-01 Director), 13 June 2003, AND Department of National Defence. E*xperiment Report – 001/2003 (QUICKLOOK) pacific Littoral ISR Experiment – Part 1* (Ottawa: DND Canada 2003), 5.

[86] Walters, Brett, French, Jon, and Barnes Michael, "Modeling the Effects of Crew Size and Crew Fatigue on the Control of Tactical Unmanned Aerial Vehicles (TUAVS)," *Proceedings of the 2000 Winter Simulation Conference J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick.* Army Research Lab Fort Huachuca Field Element, Greely Hall, Room 2631,Fort Huachuca, AZ 85613, U.S.A..

addition of one designated individual as the TUAV pilot.[87] Finally, the end result in the employment TUAV's should be the ability to "File and Fly" in all airspaces. MH pilots currently have the knowledge and ability to do it, are already a part of the MAG and Navy team, and fundamentally understand how the asset will be employed in support of Navy requirements.

As a final note on personnel composition, the ability for a HALIFAX class to embark a TUAV & MH combined detachment for OGD support operations would be appreciably easier. In this type of operation, the ship would be able to risk manage the crewing mix with greater latitude (given the non-combat nature of the operation). This flexibility when conducting domestic operations would also allow CEC, RCMP and/or DFO teams etc. to billet onboard for the duration of an operation.

Training Considerations. As new combat capabilities are developed and the associated equipment introduced into the Navy, there has often been no corresponding reduction in the requirement to crew and support already existing systems. Over time, this has resulted in combat department sections not being able to concurrently operate all existing combat systems and in maintainers being taxed to the limit to meet system knowledge and maintenance requirements. A corollary to this problem is the dilution of training on the wide range of equipment. Therefore, when introducing a new capability, being able to effectively address the training burden is of prime importance. There are four areas where training touches TUAV integration: pilot training, payload and vehicle maintenance, payload operator training, and sensor information exploitation training.

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[87] Five trained (interchangeable) MH / TUAV pilots can best meet the crewing requirements of both assets. Further, an additional MH pilot in the detachment gains operational flexibility in the face of a grounding head cold/twisted ankle, as there would still be two full crews available and a TUAV pilot.

Given that TUAVs are operated remotely, significant portions of pilot TUAV training in the Transition, Mission Qualification, Proficiency and Continuation phases will be largely (if not fully) supportable by simulated flight training processes. Figure 11 effectively points out how TUAV training can be supported by simulation. Simulation training (vice live flight hours as is required in MH pilot / crew training) will preserve valuable airframe flight hours, avoid the associated maintenance tag, and be flexible to program and maintain (both ashore and on deployments). Further, automatic landing and advanced flight processes (e.g. point-click, fuel calculation algorithms etc.) will ease pilot conversion training.

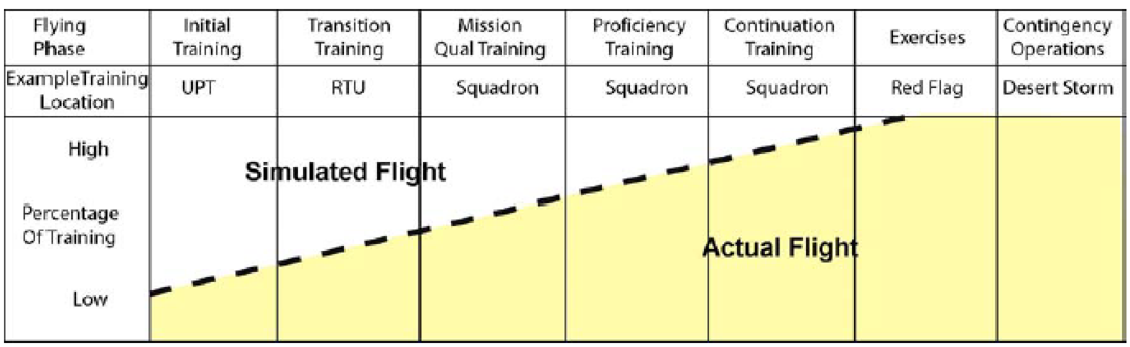

Figure 11. TUAV Pilot Demand in Actual vs. Simulated Flight Training.[88]

TUAV vehicle and payload maintenance are areas where effective contract management will ease the transition. Initially, contractors will play an important role in all maintenance areas and will provide long-term 3rd line maintenance.[89] After an initial training period, it is assessed, given relatively simple and commercial nature of TUAV

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[88] United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 52.

[89] A business case analysis may show it to be cost effective to ship TUAVs to the manufacturer / contractor for 3rd line maintenance and inspection as is done for current Navy missile systems.

airframes and components, that MAG technicians can acquire the skill sets that would be required for 1st and 2nd line TUAV vehicle maintenance. Advances in COTs and on-line software-based training and maintenance programs can be employed in a classroom setting, on the shop floor, and in the ship's hangar.

Based on the initial results of the PACIFIC LITTORAL Quicklook report which stated that the NCIOP and NESOP combat trade operators were able to effectively operate the MALE UAV sensors (without any formal training), it is assessed that Navy personnel will be able to fulfil the payload sensor operator role. The report also cited that "air sense and operational experience, spatial awareness, and the cognitive skills associated with thinking in three-dimensions" were important for MALE UAV operations.[90] These attributes are known qualities of Navy air controllers and to varying degrees NCIOPs and NESOPs such that modest training and experience will enable combat personnel to meet the remit of the sensor operator role.

In support of operations where intelligence collection will be a requirement (e.g. DCDS operational deployments), it is envisaged the embarked intelligence officer and CDSE team personnel would be able to meet the sensor information exploitation requirements. Further, the option exists, when intelligence personnel are not embarked or higher-level analysis is required, to forward imagery or collection information via net-centric technology for detailed analysis.

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[90] Department of National Defence. Experiment Report – 001/2003 (QUICKLOOK) pacific Littoral ISR Experiment – Part 1 (Ottawa: DND Canada 2003), 10.

Section 5: TUAV – Operation and Support Issues – Operations

Tactical Unmanned Aerial Vehicles offer a number of striking advantages. Unmanned, they are expendable on high risk or mundane missions, are easily transportable, can be flown at a higher operational tempo than manned aircraft, offer increased flying hours with less maintenance and personnel requirements, provide near real-time direct intelligence feeds to the ship, support joint and constabulary operations in many cases better than MHs do, and will have consistently state-of-the-art sensors. This section will touch on this long list and show why TUAVs are worth the cost and effort to introduce them to the CF.

The key advantage of TUAVs is that they can be put in harm's way to accomplish a vital mission with no risk to CF personnel. To highlight how TUAVs can be employed in support of high-risk missions, a review of UAV mission categories is appropriate. The US DoD categorizes missions as Dull, Dirty, and/or Dangerous (D^3) to caveat essential but boring tasks, NBC environment tasks, and high-risk tasks.[91] The following table combines two UAV Roadmap 2002 tables[92] to illustrate the broad range of missions that TUAVs will be able to support and which of the D^3 categories they carry. It is notable that the top three missions are core areas that the Canadian Navy would look for TUAVs to be able to support and that the number one mission area is currently being provided to the Canadian ISAF contingent by the Sperwer TUAV in Afghanistan. Also, they are all

[91] Edward H. Lundquist, "Drone Duties: The Dull, the Dirty, and the Dangerous," *Naval Forces* (3 2003): 20-24.

[92] United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 26 and 28.

assessed as “Dull” functions[93] with the Intelligence Surveillance and Reconnaissance function also assigned a “Dangerous” caveat. This table sheds light on how TUAVs, a much more effective and efficient sensor in these mission areas, can meet the essential but “Dull” needs of the Navy. Finally, TUAVs have a central role to play in 14 of the 16 dangerous missions listed below, all at no risk to CF personnel.

TUAV Mission Priority	Mission Area	Dull	Dirty	Dangerous
1	Reconnaissance	x		x
2	Precision Targeting			x
3	Comm/Data Relay	x		
4	Chem/Bio Reconnaissance		x	x
5	Signals Intel	x		x
6	Mine Detection/CM			x
7	Battle management			x
8	Counter Cam/Con/Deception			x
9	Electronic Warfare	x		x
10	Combat SAR			x
11	Information Warfare			x
12	Digital Mapping/Navigation	x		
13	Weaponization/Strike			x
14	Covert Sensor Insertion			x
15	SOF Team Resupply			x
16	Decoy/Pathfinder			x
	Force Protection	x	x	x
	Exercise Support	x		
	Counter Narcotics	x		x
	Meteorology and Oceanography	x		x

Table 8. D^3 UAV Mission Areas, compiled from UAV Roadmap 2002 Section 3 Requirements; tables ‘3.2-1: UAV Mission Areas’ and ‘3.3-1: Combatant Commander/Service UAV Mission Prioritization Matrix – 2003.’[94]

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[93] Dull indicating a mission role that would be more efficiently performed by a TUAV than a manned aircraft assuming the TUAV able to adequately perform the mission. The ability to employ an unmanned and considerably less expensive asset to perform a dangerous mission is a TUAV strength.

[94] United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 27-28.

TUAVs are small and easily transportable. The ability to swiftly forward deploy TUAVs[95] will enable the Navy to refresh the available aviation flight hours/YFRs[96] to deployed units,[97] replace TUAVs due to loss, or to increase the total number of available maritime air assets in theatre. This flexibility is a significant operational advantage over manned helicopters.[98] As Figure 12 shows, one service flight can restore a lost capability or significantly increase the number of available aircraft.

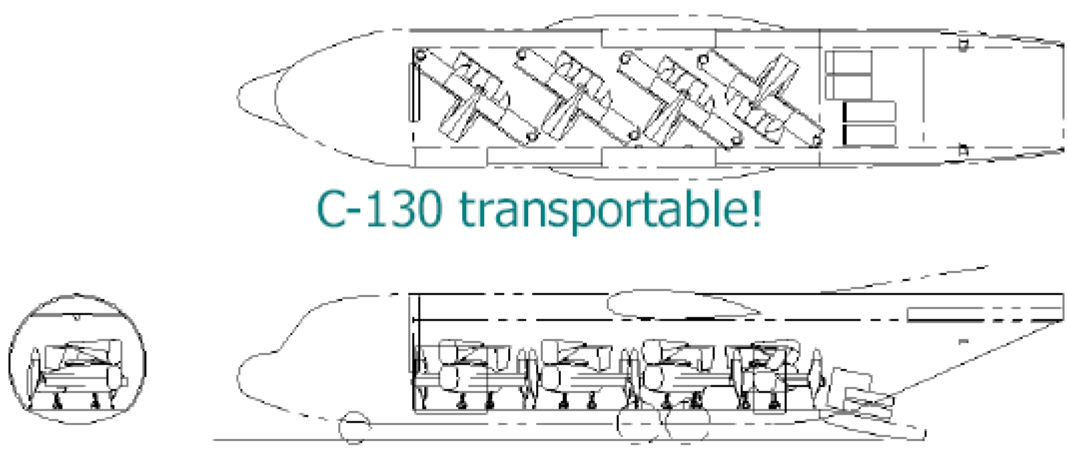

Figure 12. The Bell Eagle Eye TUAV C-130 transport configuration.

[95] Equally, deployable TUAV systems could operate ashore from NFLD, Tofino, or the Great Lakes in support of military and/or constabulary roles should the need arise.

[96] Yearly Flying Rate (YFR) or more clearly the number of flying hours that a Navy Commander can use in operations without approval from the Air Force (due to budget and maintenance management issues).

[97] During OP APOLLO near the end of Roto 0, a complex in-theatre phased transfer plan was executed involving four Sea Kings and three HMC Ships. Over the course of several weeks, helicopters were transferred between deployed ships to juggle FYR allocations and major maintenance requirements to the detriment of operational capability and stability. The author was the executive officer of HMCS VANCOUVER, one of the HALIFAXs involved in the helicopter shuffle.

[98] During OP SHARP GUARD in 1993, a Sea King suffered two different gearbox failures during the six-month deployment sacrificing over six weeks of MH availability. The aircraft had to be landed ashore at Brindisi, Italy, an entire gearbox assembly brought out with a full mobile repair party – twice. Contrast the ability to quickly repair and/or replace TUAVs to the operational restriction of an onboard MH failure, and the tremendous flexibility of the TUAV system becomes glaringly apparent. On board failures do not result in a hangar queen and most TUAV systems are light enough that they can HDS'd to the ship from ashore by MH.

The addition of TUAVs to the Navy toolbox offers a commander increased operational flying tempo and greater available flying hours to dedicate to the mission. Historically, a TG comprised of one AOR, one IROQUOIS, and one HALIFAX class deploys with four MH's and their associated detachments and has had available 1800-2000 YFRs available for operations (approximately 500 flying hours per MH).[99] This level of available YFRs cannot sustain operations for an extended near-combat operation or surge combat operation deployment.[100] A TUAV and MH mix will mitigate this deficiency and offer 1000 MH YFRs for task tailored operations and a significantly higher number of TUAV YFRs for dangerous and dull operations.[101] Add to the relative increase in available flying hours for combined TUAV – MH operations over MH operations, the ability to forward deploy or bring out additional or replacement TUAV vehicles/payloads via Hercules, airbus, or stored in the Joint Support Ship and one starts

[99] Historically, this practical limitation on assigned YFR has taken into account the major periodic maintenance requirements of the CH124A. The MH replacement may afford marginally greater flexibility in the number of assignable YFRs per deployment.

[100] The MH SOR assesses the TG flying hour requirement in support of an operational deployment for near combat operations to be 120 flying hours per MH per month (based on 1 MH airborne 24/7). This requirement doubles for surge combat operations to 240 flying hours per MH per month (2 MH airborne 24/7). These figures consider that a TG has available 6 MHs for operations to be able to support single MH 24/7 flight operations. Given MH and detachment availability, recent TGs deployed with 4 MHs. To sustain a 24/7 near combat operation tempo for a four-month on-station period, this would require 720 flying hours per MH not including enroute training and return transit flights. This level of activity is clearly beyond the Sea King's limitations and likely beyond the MH replacements as well given major supplemental maintenance requirements. Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 17/47.

[101] A generic TUAV/MH TG model would be comprised of one TUAV in a HALIFAX class, one MH in an IROQUOIS class, and one MH and one TUAV in the Joint Support Ship. Given the space available, the option exists to box and store additional TUAV vehicles in the JSS to efficiently refresh YFRs mid-deployment if required. It is equally possible that the JSS will be able to either conduct major maintenance to organically refresh TUAV YFRs or alternately embark contactor technicians for that purpose.

to appreciate the enormous flexibility that TUAVs offer.[102] Finally, the operational tempo of CF personnel has become a limiting factor in operations. Overall detachment requirements in a TG with TUAV/MH asset mix would reduce operational tempo demands.[103] In sum, TUAVs will offer increased force generation capability, flexibility, and efficiency for the Task Group.

Considering a HALIFAX class that deploys on a DCDS operation with both an MH and a TUAV, the flexibility and efficiency afforded by the addition of a TUAV in general is augmented by a significant increase (more than two times the MH allocation) in available deployment flying hours for the HALIFAX class detachment. In addition to the doubled (plus) flying rate, a mixed TUAV / MH capability set would represent a much more attractive force generation contribution to a carrier Battle Group or coalition operation. Consider the significant capability set of a MH and TUAV equipped HALIFAX class (e.g. capable of surging to near continuous deck cycle operations) with an embarked CDSE intelligence team capable of exploiting near real-time tactical and operational level intelligence information. This level of contribution to would earn greater diplomatic and military visibility as compared to a traditional MH equipped HALIFAX class (12 hour deck cycle) with an intelligence team embarked.[104]

The traditional deck cycle of a HALIFAX class is 12 hours of flight operations within a 24-hour period. This deck cycle permits the helicopter to be fully maintained

[102] Due to their small size and compartmentalized nature, a TG could bring to theatre replacement or additional TUAVs to increase the number of organic maritime air assets in total, add to the force sensor capabilities, and/or refresh available YFRs for higher tempo operations. Flexibility is further increased, as TUAVs are small enough to be HDS'd from ashore to at-sea units.

[103] A TG with one IROQUOIS with an MH, one HALIFAX with a TUAV, and one JSS with a TUAV and MH detachment would require 3-4 fewer pilots, 2 fewer navigators, 2 fewer AESOPs and 8-10 fewer technicians.

[104] Which effectively replaces a USN frigate capability with little added advantage.

and crew rest accounted for. Assuming an availability of at least 12 hours per 24, TUAVs offer the option in a combined TUAV and MH Air Detachment of continuous 24/7 air operations if the circumstances warrant it and personnel can do it. It is beyond the scope of this paper to advance a definitive position on the feasibility of continuous 24/7 air operations for extended periods of time as that assessment would require a detailed TUAV and MH maintenance, workload, and crew composition study to validate. That said, based on U.S. Marine Corps and U.S. Navy experience, a combined TUAV and MH air detachment could have the ability to surge continuous air operations for a short period of time and then maintain sustained air operations for up to18 hours per day thereafter.[105]

The employment of TUAVs will fundamentally increase the level and timeliness of data available to be fused into the ship's Command and Control System. The quality and quantity of radar, electronic warfare signal, meteorological etc. information that a TUAV can fuse directly into the HMCCS is impressive and would combine many of the best aspects of a MHs and Link[106] fitted Long Range Patrol Aircraft. Currently, the MH statement of operational requirement does not stipulate the need for a data link from MH sensors to the ship, which is a significant drawback to what TUAVs have to offer.

The CF has an opportunity to fundamentally increase joint Army, Navy, and Air Force operations by selecting a common TUAV to act as a gateway technology. Owned and operated by the Air Force, TUAVs could be fielded as an embedded capability within

[105] U.S. Marine Corps UAV concept of operations permits surges for continuous air operations for 3 days maximum and then revert to 18 hours a day, which could be sustained indefinitely. Onboard a HALIFAX/IROQUOIS, numerous factors will come into play to define what a MH / TUAV detachment Deck Cycle will be including automatic landing technology, advanced flight control processes etc.

[106] LINK is essentially a military modem that allows streamlined combat system data to be exchanged by participating warships over UHF radio waves at sea in order to create a common operating picture.

the Army and the Navy much as TAC HEL and MAG are. Recent DCDS operations have involved CF land and naval forces, operating within 100 nm of each other (e.g. FRY, Somalia, East Timor etc.) and this trend (possibly Haiti in the future?) is likely to continue. The Navy would be in a position to directly contribute to the Army's situational awareness through littoral intelligence collection. Both the Navy and the Army alike would receive direct feed from sea-based TUAV sensors, providing a common operating picture to both elements. When necessary, control of CF TUAV assets could be passed between the Army to the Navy as the need arose with joint maintenance agreements, fuelling arrangements etc. to take advantage of economies of scale and support. TUAV – a joint force gateway!

As a system within the overall surveillance system, TUAVs will greatly enhance DND's and CF's ability to support domestic and continental constabulary naval roles. Employing net centric technology, an OGD will be able to quickly assess timely information, provide direction, and/or act upon TUAV sensor information. It is important to realize that TUAVs can also operate from shore and are ably suited to support internal waters security requirements. TUAVs have the capacity to augment internal waterway coverage in support of Public Security and Emergency Preparedness and Transport Canada maritime security requirements much as the Department of Homeland Security is studying the utility of TUAVs for homeland defence.[107] Deployable truck TUAV systems (similar to the Dragon Warrior depicted below at Figure 13) are a considered a flexible capability to acquire at relatively little additional system cost. TUAV responsiveness, operational persistence, and timely information

[107] *USA Today Magazine*, "Homeland Security – UAVs Next Step to Stem Terrorism," Vol 132, Issue 2703 (December 2003): 1.

transmission offer an excellent solution to the Great Lakes surveillance requirement.[108] In view of this interdepartmental application and level of national security support, joint DND, DFO, PSEP and Transport Canada TUAV system funding is an option to explore to mitigate the modest TUAV acquisition cost.

Figure 13. Dragon Warrior High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) and trailer.[109]

The TUAV payload will represent a significant portion of the total TUAV system investment. Consequently, decisions as to which capabilities are required to meet CF and Navy requirements are very important. The acquisition of optical systems (electro optic and infra red), Synthetic Aperture Radar, and a communications relay module are considered to be baseline TUAV capabilities. Beyond those, technological advances and the production-ready designs at the time of system selection will drive which additional, if any, payload capabilities that the CF should buy or invest in.[110] It is important to

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[108] For example, control sites at Hancock Wisconsin, and Owen Sound, Saint Thomas, and Trenton Ontario would afford near 100% coverage of lakes Superior, Huron, Erie, and Ontario. In conjunction with the AIS system, the use of two TUAV's with portable control stations, an effective surveillance matrix, and assets ready to respond to arisings would represent a very cost effective and graduated response approach to this important surveillance area (both from a practical and political view point).

[109] United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 13.

[110] The ability for every TUAV mission to update meteorological information for radar and gunnery prediction purposes would be extremely valuable. Satellite relay of TUAV sensor information directly to the ship, the MOSIC or the JTF Commander would reduce shipboard communication demands and further improve decision cycle dominance. Additionally, the technology to support chemical and biological agent detection capability exists today and is rapidly maturing.

remember that TUAVs have excellent intrinsic growth potential. The plug and play nature of the TUAV technology is such that generation advances in any one piece of the payload toolbox will permit rapid operational integration and exploitation (whereas the design requirements of adapting new technologies to MH are very restrictive, expensive, and relatively time consuming).[111] TUAV options such as leasing a payload sensor may also represent a cost effective short-term mission specific capability acquisition that is simply not possible for a MH.

Section 6: TUAV – Conclusion

This paper argues that TUAVs are an essential organic maritime aviation complement to MHs and that the CF can integrate TUAVs in support of the Navy within the existing infrastructure. This chapter illustrated that incorporating TUAVs into the Navy and MAG is feasible, in many respects straight forward, and that options are available at each stage to tailor TUAV integration in a manner that best meets the needs and resources of the CF.

From an equipment perspective, TUAV integration in the Fleet is fully achievable though there are challenges. First, while there appears to be the growth potential in the HALIFAX class and JSS to accommodate the GCS and PE terminals in the operations room or in close proximity, the IROQUOIS class is a larger strategic issue. Second, the TUAV variant ultimately selected will have unique capabilities but will also have unique requirements. The level of modifications to support launch, recovery, and storage are diverse ranging from containerized storage requirements to potential alterations to the

[111] Department of National Defence, *Statement of Operational Requirement: Maritime Helicopter*, DSP No 00002680 (Ottawa: DND Canada, 2003), 24/47.

recovery system. In each of these areas, different TUAV variants offer options depending on the desired TUAV capability set and available CF resources. Finally, the Maritime Air Group shore infrastructure is well suited to support TUAV equipment requirements.

In this age of personnel shortages, personnel tempo limitations on operations, and the pressure to accomplish more with less, TUAVs offer a solution. The core skills sets and training to maintain and operate TUAVs already exist largely within the CF. Maritime Air Group pilots can effectively learn to fly this remotely operated aircraft pre-dominantly utilizing inexpensive and accessible simulation techniques in such a manner as not to impact on their other flying duties. The Pacific Littoral Exercise demonstrated how, without any formal training, naval personnel were able to effectively operate state-of-the-art UAV electro optic/infra red and synthetic aperture radar sensors and in the first time operating the equipment catch a vessel polluting our waters. Finally, Maritime Air Group technicians have the ability to port their considerable military air maintenance skills to absorb the technical requirements of a small, commercial TUAV airframe with a simple propulsion system. Again, options exist to mitigate challenges in all areas. Finally, TUAVs offer an increased capability while mitigate critical personnel tempo limitations on operations. In particular, Maritime Air Group operational tempo would be further eased, as small TUAV detachments could support local / short notice tasking requirements and, in the case of exercise or operational deployments, a mix of complementary TUAV and MH assets would increase efficiency, flexibility, and capability at a lower operating cost and personnel bill.[112]

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[112] Comparing a TG comprised of one IROQUOIS with an MH, one HALIFAX with an MH, and one JSS with two MHs to a TG of one IROQUOIS with an MH, one HALIFAX with a TUAV, and JSS

From an operational perspective, TUAVs have much to offer the CF. As unmanned intelligence, surveillance, and reconnaissance aircraft, they can support the Army and Navy's operational requirements and voracious appetite for information without risk to soldiers, sailors, and airmen as is currently the case for ISAF in Afghanistan. In this vital joint function, they will be able to provide near instantaneous information injects to the decision cycle, all the while flying at a higher operational tempo and offering more total deployment flying hours. TUAV state-of-the-art gateway technology sensors and communications equipment will improve the quality of information, enabling the CF to better meet its constabulary, diplomatic, and military roles.

Chapter 6

TUAV Benefit Analysis

Section 1: TUAV – Introduction

The assertion of this paper is that TUAVs are an essential augmentation to MHs in HMC Ships. As TUAVs will be a Maritime Air Group asset and function as a complement to MHs, a number of cost comparison factors are not applicable. For example, TUAVs would be operated utilizing the same overall Maritime Air Group shore infrastructure and as such will be largely cost neutral from an overhead perspective (e.g.

with a combined MH/TUAV detachment, the TG with an MH/TUAV blend reduces personnel requirements by 3-4 pilots, 2 air navigators, 2 sensor operators, and 8-10 technicians. Further, exercise requirements and crucial but "dull" constabulary operations (e.g. fisheries patrol) could be met by a TUAV detachment when necessary resulting in 2 pilots, 1 air navigator, 1 sensor operator, and 5-7 technicians not having to deploy.

hangar space, lighting etc). Therefore, measures to compare TUAV costs to other organic air asset costs will be limited to personnel and operating costs. Finally, amortization and life cycle costs will also be discussed to provide perspective to the cost to the CF over the life of the asset in addition the relative rates of technological obsolescence. For ease of comparison, this chapter will Compare where possible the CH124A and Cormorant MHs to the Fire Scout, Eagle Eye, and the Pioneer TUAVs.[113] This chapter will demonstrate that TUAVs offer their considerable capability set at a very affordable and sustainable cost.

Section 2: TUAV – Operating and Support Costs

In evaluating operating costs, TUAVs can tailor a broad range of capabilities in support of D^3 missions in a very efficient manner. Mission for mission, TUAVs cost less to operate and support than MHs and therefore offer both short and long-term economies of scale. The most striking component when comparing operating costs is fuel consumption.

From a fuel perspective, the MH is an SUV whereas the UAV is a compact car. Table 9 was constructed to provide a comparison of the fuel costs for the MH and TUAV, illustrating the drastic difference in fuel consumption.

[113] These TUAVs were selected as they represent the smaller and larger TUAV design options, have comparable endurance to MHs, and have payload capacity permitting advanced configuration options.

Aircraft	Endurance (hr)	Fuel Consumption (l/hr)	Fuel (lbs)	% of HALIFAX Aviation Fuel Capacity for a 3.5 hr mission
CH124A	3.5	604	3760	3%
Cormorant	4	1100	7830	6%
Pioneer	5	38	67	0.2%
UAV Fire Scout	5	89	793	0.5%

Table 9. TUAV Fuel Consumption Characteristics [114]

From Table 9, two significant observations can be made. First, TUAV variants make very efficient use of ship fuel capacity offering excellent endurance versus fuel consumption as compared to MHs (requiring approximately 1/5th or less the fuel that an MH does). Specifically, TUAVs will be able to dramatically increase the number of available organic air asset flying hours between ship RAS operations (to replenish aviation fuel).[115] Second, TUAV endurance and on-station times can be expected to be the same or better than an MH. In addition to fuel, there will be economies in maintenance.

The Sea King is infamous for the necessary number of hours of maintenance per flying hour. The Cormorant has the advantage of modern design and thus requires significant but fewer hours of preventative maintenance per flying hour. In sum, it requires a team of eleven maintainers in a traditional air detachment to maintain these two types of aircraft. In contrast, the Bell Eagle Eye can be maintained by a team of two

[114] This Table was constructed from Table 3-1 Aircraft Costs - Rates Per Flying Hour (FH) - FY 2003-2004 $ from the CF Cost Factors manual, the 2002 UAV Roadmap, and Bell Eagle Eye factory information. Endurance figures were calculated by dividing the max fuel capacity of the aircraft minus a 600lbs reserve and dividing by the fuel consumption rate (utilising a fuel conversion factor of 1.78 lbs per litre).

[115] For example, dedicated use of a TUAV variant such as the Fire Scout would yield over 700 YFRs based on a 64Cum capacity resident in a HALIFAX class. This is considerably greater than the 106 and 58 YFRs that the Sea King and Cormorant would offer. Figures are calculated using the 64 cum capacity divided by the L/Hour consumption rate of the airframes.

and requires typically less than 1 hour of maintenance per flying hour.[116] While each TUAV variant will have unique maintenance characteristics and personnel requirements,[117] it is assessed that by virtue of their small size, fewer onboard systems (e.g. no man-machine-interface components / controls), generally simple propulsion design (basic two or four stroke engine that may be adapted to employ heavy aviation fuels), and commercial components, modern TUAVs will require appreciably lower maintenance hours per flight hour.[118] Thus, considering favourable endurance, fuel, and maintenance characteristics, TUAVs have the ability to operate much more efficiently than MHs can. Does this translate into more efficient mission operations though? The facts say yes.

In considering area search efficiency, speed, altitude and radar coverage / discrimination are key elements. TUAV variants have cruise speeds and operating ceilings that compare favourably or better to the Cormorant. It is assessed that TUAV synthetic aperture radars will match (if not outperform as generations advance) the MH replacement's radar (which will not be a synthetic aperture radar and which may never be upgraded over the life of the asset). Further, synthetic aperture radars have the ability to assess/image target size and class from long range and/or outside promulgated standoff ranges, providing a valuable capability and improving search efficiency and

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[116] USCG Eagle Eye detachment consists of 2 pilot/operators and 2 maintainers.

[117] For example the ISAF experience with the Sperwer TUAV is that it is a labour intensive system requiring up to 80 man-hours of maintenance per mission. Major J. Gobin, DPM LF ISTAR (UAV), e-mail correspondance, 6 April 2004. The high maintenance figures reflect the austere operating environment and its parachute and land impact recover style. That said, it is a fair operational assessment of early generation TUAV technological requirements.

[118] The Bell Eagle Eye requires less than one maintenance man hour per flight hour, has a 1.5 mean time to repair, and has in excess of 190 hours mean time between mission effecting failure.

effectiveness. Finally, the near real-time feed of radar information via the TUAV-Ship data link will also greatly enhance the completeness and accuracy of the operating picture over the traditional MH-Ship voice report and manual update process. Thus, TUAVs will be able to effectively execute intelligence, surveillance, and reconnaissance tasks at a greater level of economy and efficiency.

Section 3: TUAV – Personnel Costs

A review of Table 3-1 in the CF Cost Factors Manual highlights the significant SWE[119] funding and hence the importance of the personnel component in MH operations. However, this is only half the story. The corollary to funding is personnel operational tempo and how it can become a limitation on CF operational capability. After the surge of OP APOLLO, the Navy observed an operational pause to permit crucial regeneration of its personnel and equipment. This pause was perhaps most necessary for the Maritime Air Group who arguably had the highest operational tempo amongst Navy deployers (to the extent that HMCS REGINA deployed on OP APOLLO without an air detachment as one could not be regenerated). TUAVs offer a solution. In a Task Group, they would require fewer Maritime Air Group personnel while increasing the number of flying hours, the flying rate, and increasing MH efficient utilization.[120] Overall, the introduction of TUAVs as a complement to MHs in maritime operations would significantly ease the Maritime Air Group personnel tempo burden.

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[119] Salary Wage Envelope or cost of salaries

[120] For deployed TG operations with two MH and two TUAV embarked air assets, there would be a TG air deta

Assessing the personnel training costs for TUAV operations is challenging. An MH pilot can learn to fly a remotely operated vehicle such as a TUAV. As discussed in Chapters 4 and 5, simulation will be able to support the lion's share of training requirements at a fraction of the cost of training on a MH (appreciably fewer live hours required for initial and proficiency training and those live hours required are also cheaper per hour to fly). Maritime Air Group MH technicians are assessed to have the core skills to maintain a TUAV. That said, contractor conversion training will be required and will likely be phased in during the challenging Sea King-to-MH replacement transition period. Shipboard training requirements will be less demanding. Adapting the core of the shipboard Chapter 9 organization to support TUAV / MH operations beyond a 12 hour deck cycle is assessed to be manageable, however the incremental training development and execution will require Navy energy if not resources. Finally, observations from the PACIFIC LITTORAL Experiment validate the assumption that combat operators have the skill sets to control TUAV payloads. However, exploitation of tactical level information (e.g. Battle Damage Assessment) is not a current operator skill set and will require support from intelligence personnel.

Section 4: TUAV – Lifecycle

While it may be attractive to acquire a new capability and it may be possible to incorporate it within the CF's infrastructure with relative ease, if the cost is excessive then the venture is not worth pursuing. Lifecycle costs are an appropriate and holistic way to consider the long-term financial impact of a capability acquisition. In view of the scope of this paper, the lifecycle assessment will be limited to acquisition, reliability, sustainment, and obsolescence.

Before discussing the various costs of a TUAV system, it is appropriate to keep them in perspective as compared to the valuable asset that they will complement, extend the life of, and undertake dangerous and tedious missions on behalf of – the manned Maritime Helicopter. On 17 August 2000, the Ministers of Public Works and National Defence announced the commencement of the MH procurement project for 29 Maritime Helicopters. The project was assigned $2.9 billion dollars to be split over 8 years and will be divided between Basic Vehicle, the Integrated Mission System, and In-Service Support. The Letter of Intent further stated that a maximum of $925 million would be spent on the Basic Vehicle and $925 million on the Integrated Mission System. Therefore, assuming the project is on budget, the total cost would be $100 million per MH. If considering the cost of just the Basic Vehicle and the Integrated Mission System, the cost per MH would be in excess of $63 million. Keeping these dollar figures in perspective, the review will turn to TUAV costs.

TUAV acquisition costs are most simply viewed employing Empty Weight Cost and Payload Capacity costs of $1500 and $8000 USD per pound respectively.[121] For example, the Pioneer TUAV would be $650,000 USD per vehicle and the Fire Scout TUAV would be $1.8 million USD per vehicle.[122] Their respective overall system cost would be $7 million USD for 4 vehicles and $14.2 million USD for 3 vehicles (including their associated control terminals and payloads). These overall system costs are in stark contrast to those of the MH above. While each TUAV system will have different price

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[121] United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 32.

[122] These vehicle costs compare favourably to the price of one ESSM or harpoon missile (between approximately $750,000 - $1,000,000 per missile plus the cost of production support and in-service support).

tags, and keeping in mind that associated research and development costs must also be accounted for, the overall vehicle cost metric of $1500 USD and payload metric of $8000 USD are ‘pound for pound’ affordable.

As a relatively new capability, TUAVs do not have a proven record in terms of reliability and survivability.[123] Given the expense of these assets, this is a critical factor to consider. Early generation Pioneer TUAV versions suffered poor reliability and hence would not be an appropriate capability investment for the CF. However, as new generation TUAVs emerge such as Bell’s Eagle Eye, reliability is becoming a TUAV strength vice a liability. The Eagle Eye has statistically shown a Mean Time Between Critical Failure in excess of 3000 hours of operation and a Mean Time Between Mission Essential Failure of in excess of 190 hours. This level of serviceability compares very well with MHs.

In terms of sustainment, an advantage of TUAVs is their relatively low maintenance requirements. Again, considering the emerging generation of TUAVs that the CF will be considering, maintenance requirements can be expected to be very low but this may not be the case with all variants (the Sperwer TUAV requires approximately 80 hours of maintenance, pre and post flight checks versus the Eagle Eye which requires less than one maintenance hour per flying hour).[124] Low maintenance requirements will have

[123] TUAV’s offer the promise of lower system cost, lower cost per pound to produce, and lower operating costs than manned aircraft. The last of these three expectations places emphasis on the link between affordability and reliability. Increased reliability will be important in earning the support of the public, OGDs, the aviation industry and organizations, and the FAA (in terms of regulatory acceptance). The UAV Roadmap 2002 defines Reliability (expressed as a percentage) as “the probability that an item will perform its intended function for a specified time under stated conditions.” United States. Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap 2002-2027* (Washington, D.C.: U.S. Government Printing Office, 11 March 2003), 187.

[124] Major J. Gobin, DPM LF ISTAR (UAV), e-mail correspondence, and Bell Eagle Eye company presentation.

correspondingly small maintenance teams (e.g. the USCG detachment composition is four: two pilot/payload operators and two maintainers) to maintain the simple engine and airframe components.

It would be naive to think that the CF could operate TUAVs indefinitely without a critical TUAV failure and Fleet composition must account for attrition due to combat or malfunction much as the MH SOR has factored a loss of 4-7 MHs over the life of the Fleet.[125] However, the loss of a $2,000,000 TUAV represents less than 1/30th the cos19 Tm(the cos)Ta453.

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Section 5: TUAV – Benefit Analysis Conclusion

In preceding chapters, it has been demonstrated that TUAVs offer operational flexibility, capability, and advantage. They will contribute in all the maritime roles and spheres of operation and, in many ways, do so better than a maritime helicopter can. This chapter has shown how all these advantages come at an affordable cost, both in acquisition and sustainment.

Representing just a small percentage of the cost of an MH to acquire, TUAVs will extend the life and effectiveness of this valuable and expensive manned aviation asset. Equally, very modest TUAV operating and maintenance requirements will enable the commander to surge the flying rate and not suffer current MH restrictions due to manned aircraft flight safety, maintenance, or high fuel/flight hour consumption. Personnel tempo benefits will be realized as well. Task Group TUAV & MH detachments will ease the personnel burden and TUAVs will be able to support many OGD support tasks with a considerably smaller detachment and without expending valuable MH flying hours. The ability of TUAVs to extend the service life of the MH while, itself incurring very affordable life cycle costs, is a major benefit. Finally, TUAVs have the ability to meet the joint needs of CF (simultaneously accruing economies of scale and service support) and other government departments. Thus, there is the possibility that acquisition and life-cycle costs can be apportioned beyond the CF.

Chapter 7

Conclusion

High ground offers three strategic assets: greater tactical strength, protection from access, and a wider view…. The occupation of high ground can thus mean genuine domination. Its reality is undeniable.

Car Von Clausewitz
On War

This paper has argued that TUAVs are an essential organic maritime aviation complement to maritime helicopters (MH) within the Canadian Navy. It is important to realize that TUAVs are not a panacea; they complement MHs and cannot replacement them. There are certain key tasks that the Navy needs that are uniquely suited to MHs such as helicopter delivery service, ASW, and direct boarding party support and there are times when a human on the scene is crucial to situational awareness. That said, TUAVs are an excellent complement to MHs in operations across the spectrum of conflict due to their tremendous operational capability, flexibility, and affordability, all of which can be effectively integrated into the CF.

Naval operations can and do occur across the spectrum of conflict and the globe. In trying to develop a capability requirement model that would capture the essence of this reality, eleven force planning scenarios were developed that incorporate what the Navy needs to be able to do. TUAVs that exist today and the second-generation variants that are emerging are able to support Navy requirements in all these scenarios. Not only contribute, in many regards their capabilities surpass those of the MH. TUAVs have the capability to support operations wherever (domestic, continental, and international), and whatever (constabulary, diplomatic, and military) the CF and Navy will need them to do.

TUAVs will save lives.[127] Unmanned, they can be employed where risk would preclude sending a manned aircraft. The freedom of action to risk an asset for information is a much simpler decision for a commander on the scene to make than risking the CF's most valuable resource – its people. The commander of ISAF, MGen Leslie, fully recognized the inherent value of acquiring surveillance information via TUAV versus sending his troops through an Afghanistan minefield at night.

Leadmark states that "… emerging technologies and evolving concepts of command and control will allow the unique capabilities of the navy to join more effectively than ever with the army and air force."[128] TUAVs represent a gateway technology to make this vision a reality. The ability to tailor the TUAV payload package to include mission essential payloads (e.g. meteorological, SIGINT, wet film, NBCD etc) enables Command to increase the range of sensor input. This, in conjunction with the Navy's ability to reduce the UAV logistics footprint ashore for the Army, will greatly enhance Joint Army / Navy operations. Similarly, TUAVs offer the ability to drastically advance and streamline DND – OGD cooperation and support . Near real-time interdepartmental information flow from sensor to MOSIC in Ottawa will afford the

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[127] "The scene could be anywhere Naval Aviators gather at day's end. Frequently, the talk turns to, 'What did you do during Desert Storm?'

For a select few Navy and Marine Corps veterans, the response could be, 'I flew unarmed reconnaissance aircraft in Iraq and Kuwait.'

'Yeah? See much action?'

'Some I was shot down twice and crashed three aircraft.'

And, if it never comes to light that the brave aviator was flying his 'unarmed reconnaissance aircraft' – in reality, an unmanned aerial vehicle (UAV) – while sitting warm and safe in a ground control station far from the scene of action, why spoil a good war story? Ray Coleman, "New Horizons for Unmanned Reconnaissance Aircraft," *Naval Aviations News* Vol 77, Issue 3 (March/April 1995).

[128] Department of National Defence, *Leadmark: The Navy's Strategy for 2020*, (Ottawa: DND Canada, 2001), 9.

government of Canada the ability to know in detail what is occurring within this country's area(s) of responsibility and act decisively to protect our nation's vital interests.

There are challenges to smooth integration of TUAVs within the CF. However, these are worth the effort to address based on the operational, joint, and interdepartmental benefits that will be realized by TUAVs. Further, they are offset by the life-cycle efficiencies that will be accrued. There is a wide range of TUAVs and each offers options to consider (e.g. fuel, landing technology requirements, system cost) that will best meet the resource and capability needs of the CF.

There will be costs involved in the acquisition of a TUAV capability within the CF in terms of research and development, system selection, and in service support. Low system expense coupled with a vehicle cost that is just $1/30^{th}$ of an MH (assuming the MH replacement comes in on budget) points to the relative value of TUAVs versus the MH. Further, requiring approximately $1/5^{th}$ the fuel, a magnitude less of maintenance, and having the ability to be airlifted into theatre, TUAVs offer excellent operating and personnel efficiencies, and operational flexibility for the commander (e.g. less requirement to replenish aviation fuel, greater number of flying hours available, replace aircraft lost to battle or damage). Finally, TUAVs have the potential to significantly extent the life of the expensive MH by undertaking 'dull' but essential tasks such as surveillance. This, coupled with the ability to mission tailor and incorporate leading technologies into TUAVs (through payload acquisition or lease) will ease pressure to modernize/force a design change on the MH over time, while avoid the impact of obsolescence.

The CF needs to aggressively pursue acquiring a TUAV that is suited to naval employment as soon as possible. The CF experimentation Centre and the Army are on the right track but the speed and joint energy needs to be increased. If acquired in concert with the MH replacement, integrated within JSS at the design stage, and fused into the HALIFAX class's Command and Control system during the FELIX midlife project, the Navy stands to reap the full measure of integration and advantage from this extraordinarily effective and efficient maritime air resource. Further, the TUAV should be selected to meet the needs of the Army (operating from ashore and from sea in littoral support) and with a view to supporting PSEP and Department of Transport maritime security requirements so as to increase the applicability and spread the costs of research, acquisition and support. Just as the Canadian Armed Forces led the world when introducing maritime helicopters to small naval combatants in 1967, the Navy is poised today to take a prominent position in leveraging TUAVs as the Future Eyes of Canadian Maritime Defence.

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