The Flawed V-22 Osprey and the Marine Corps

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"Damn the torpedoes, full speed ahead."

Admiral Farragut in Battle of Mobile Bay

I have long been impressed by the fighting capability and valor of our Marines. Despite being an Air Force fighter pilot, I have known excellent USMC fighter pilots and two brilliant ground combat Marine Colonels that rank with the best and brightest military professionals in the world. The Marines have had some superb Commandants, exemplified by Generals Alfred Gray and Charles Krulak. They have had great combat commanders and leaders, General Walter E. Boomer and Charles Krulak (again) of Desert Storm fame, and the bright, honorable, soldier-statesman General Anthony Zinni. I bristle when I hear others refer to Marines as "Jarheads" if the name-callers aren't smiling or are using the name pejoratively. The demanding assault role of our US Marines always places them in grave danger, a risk they willingly accept. The Corps, as always, continues to fight valorously and well in the extremely difficult campaigns in Iraq and Afghanistan.

But something goes awry when the Corps selects its aircraft. It will soon possess <u>two</u> compromised aircraft – the vertical rising AV-8B Harrier strike fighter, and the MV-22 Osprey tilt-rotor aircraft. Both were purchased for their vertical rise capability in addition to conventional aircraft flight, and both purchased with the Corps believing their convertability allows them to operate anywhere from prepared surfaces. In fact, *they can only operate from <u>ideally</u> prepared surfaces.* Given this misapprehension and Marine loyalty to the Corps and their commanders – *Semper Fi* – they are locked into their decisions, be they right or wrong.

The US Marine Corps has been dreaming for decades of the day it can transport its men and supplies into combat arenas with the MV-22 Osprey – an interesting, unique, convertible, tilt–rotor aircraft that combines the flight modes of a helicopter with those of a conventional turbo-prop aircraft. Why?

No rational military analyst knows.

The Osprey's origin was not the result of studied requirements to renew the Marine transport fleet. Nor was it the result of researching the available options for competitive operational analysis. The Osprey originated with an industry representative successfully lobbying Senator John Tower who was, at the time, in line to be the next Secretary of Defense. Its engineering development period has been an incredibly long 30 years – a record – and is still incomplete. It was prematurely declared operationally ready twice in the last five years. It failed two formal Operational Evaluations (OPEVALs) during this period. Despite its recent flagrant failure in June 2005, the USMC, US Navy System Program Office (SPO), and the Defense Acquisition System declared it ready for full-scale production. Incredible logic![1]

[1] The clearest presentations of the test failures are not found in the official Pentagon literature, but in a December 1, 2005, report by former U.S. Marine Carlton Meyer, *V-22 Fails Second OPEVAL* <http://www.g2mil.com/duma.htm>. The official report is *The V-22 Osprey Program – Report on Operational and Live Fire Test and Evaluation,* published by the office of the Director, Operational Test and Evaluation, the Pentagon.

The procurement of the Osprey has made a mockery of the usual competitive evaluation via flight-testing. The voting public must be told the truth in this matter. The taxpayers must be informed that they are paying exorbitant prices for degraded defense. When Vice President Dick Cheney was Secretary of Defense, he cancelled the program *for its excessive cost.* He was never informed of its manifold flaws, its military inadequacies, and the problems inherent in tilt-rotor designs. He wasn't made aware that the quoted excessive cost was far exceeded by ***its obscene real cost!*** Then the USMC persuaded the (compliant) Congress to override the actions of the Secretary of Defense and kept the program alive.

This paper evaluates the US Marine Corps' judgment with aircraft acquisitions. Further, I will take the unprecedented action of predicting the grand defense failure that the MV–22 will be for the country, a failure induced by the Corps, US Navy, Air Force, Department of Defense (DOD) Acquisition System, and the Congressional Oversight Committees. I will predict the unnecessary losses that will be "self inflicted wounds." My sympathy is less for commanders of the Corps who so willingly take the risks while degrading its operational capability, than it is for the country and the innocent Marines forced to fly and be transported by the MV-22. Their wives and mothers should prepare themselves. The USMC has been flying a vertical-rising, heavily-compromised jet fighter aircraft, the AV-8B Harrier, for years. The aircraft served poorly in two military campaigns and has been dubbed ***"The Widow Maker"*** by its pilots *for its many crashes in peacetime operations*.[2] The Osprey will do worse than the Harrier in both senses.

The devotion of the USMC to this acquisition is mostly emotional and rests on blind loyalty.[3] It ignores proper rational evaluation.[4] The Corps continually and reverently repeats two mantras that are vacuous, shallow distortions of the truth. The mantras are:

1. "The Osprey is twice as fast, lifts three times as much, and flies five times as far."
2. "The Osprey is more survivable, more maintainable, and more self-deployable."[5]

In addition to the mantras, Marine Corps generals constantly testify (expressing only opinions) that the Osprey would have significantly improved military operations in the high Kashmund mountain ranges of Afghanistan. They opine that the Osprey would have successfully recovered our embassy hostages in Teheran without the disastrous event that was the *Eagle Claw* mission employing USAF RH-53D helicopters. These unjustified opinions are given to the press which

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[2] Two extremely competent reporters for the *Los Angeles Times* newspaper, Allan Miller and Kevin Sack, wrote a series of four articles (Dec. 15, 16,17,18, 2002) describing the Harrier. They won a Pulitzer Prize for excellence in reporting. The articles are superb.

[3] Read the display of Marine emotions in the article, "The Osprey as Phoenix," in the November 2005 issue of *Proceedings*, a generally excellent military magazine published by the US Naval Institute. It is riddled with alleged data and statements that are in contradiction to formal Operational Evaluations. This will all be reviewed.

[4] Many have tried to make this clear: Secretary of Defense Cheney who cancelled the program; Col. Harry P. Dunn, helicopter expert and his "Red Team"; Joe Neff, reporter for *The News and Observer*, Raleigh, NC; OPEVALs in 2000 and 2005; Report to the Assistant Secretary of the Air Force, Financial Management & Comptroller, "The CV-22: Impacts of Performance On Cost Effectiveness," Col. Everest E. Riccioni, USAF, Ret., EMA, Inc., October 23, 2002 (Riccioni Report); and others.

[5] Since many of the characteristics are multiplicative, the mantras imply that it must be at least 10 times better – but better than what? Did anyone mention unit cost? Mantra 2's "more" is devoid of information.

then "informs" the public. Their opinions are provided as testimony to the Armed Forces Committees of the Congress. The mantras and opinions need and will receive critical review.

In combining the flight modes of conventional turbo-prop aircraft and helicopters, the design necessarily introduces *compromises* and *novel problems* into the mix, resulting in serious operational limitations. Some of the new problems are potentially lethal. So what are the Truths? What can the real Osprey accomplish? Is the design fundamentally flawed? Is it manufactured poorly? The lack of available answers to these questions reveals the limitations of those involved in its acquisition. Worst of all is their substitution of opinions for competent analysis based on test data, and "spin" for the truth.

That the concept behind the V-22 is suspect has been established by the *three decades* required for engineering development. In its operational flight tests (OPEVALs), the aircraft **failed to meet many of its Key Performance Parameters (KPPs) by large margins![6] KPPs are minimal standards set by skilled Marine aviators who expect them to be easily met.** Two competent former directors of the Department of Test and Evaluation (DOT&E), which is responsible for all military testing done by the Department of Defense (DoD) – the Honorable Dr. Phil Coyle and the Honorable Thomas Christie – declared the Osprey deficient. Yet startlingly, unreasonably, the acquisition system declared it "operationally ready" and cleared it for full-scale production. When it was deemed ready five years ago, it took several accidents and the loss of innocent Marines to bring the program managers and the Marines back to reality.[7] It will be interesting to see what this new decision brings.

The USMC is buying 350 Ospreys and the US Air force 50. The Osprey's major function for the Marine Corps is the rapid transfer of men and war materiel into combat arenas. This role is defined in the Navy/Marine operational concept, "Assault From the Sea." Another mission is the rapid recovery of downed personnel in combat. A third is Special Operations. The USAF desires it for injection but mostly for *extraction* of its Special Operations Forces in its Special Operations Command – AFSOC. The USAF also has the recovery of its downed pilots as a traditional mission, but on recognizing its unsuitability for the operation, will not use the Osprey. The US Navy appears to understand the severe problems they will have in using the Osprey aboard their ships and in rescuing personnel from the sea, because it has yet to fund its lip-service commitment to 50.

How does the V-22 measure up against its mantras? The first distortion – the mantras don't state the basis for comparison. *Comparison demands a basis.* Probing revealed that the Marines were comparing their *future high-tech dream* with *a smaller, lighter, obsolete, 40-year-old helicopter*

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6 In detailed report *V-22 Fails OPEVAL* by Carlton Meyer, editor@2mil.com, and others.

7 Interestingly, the misfortunes of the Osprey program never flagged for lack of support by "experts." After the critical accident five years ago, a so-called "Blue Ribbon Committee" was composed of a Marine General, a celebrated captain of industry, and a Professor of Astronautics and Aerodynamics from MIT. On review, the committee saw no fundamental problem in the Osprey program that could not be resolved. They provided only opinions – opinions without engineering analysis. Next, NASA Ames, the home of vertical lift science, convened 15 of the nation's leading experts on vertical lift aircraft, a distinguished group (bolstered by consultants) led by Dr. McDonald, director of the facility. They deemed tilt-rotor aircraft to be the way of the future. They, too, did no engineering analysis and provided only their august opinions. One month after their formal report hit the streets of Washington, DC, it was completely discredited. Dr. McDonald precipitously retired from NASA.

that they still use, the CH-46E Sea Knight. The Sea Knight was their workhorse in the Vietnam War, and remains such. Why not judge their acquisition against available modern combat helicopters? Answer – *to keep from disrupting their dream!* Further they compare a single MV-22 Osprey to a single CH-46E Sea Knight, one-third the Osprey's weight, and one-sixth its cost. They should be comparing it to a helicopter comparable in empty weight and engine power – the old, CH-53E. Further, they should compare diverse equal-numbered fleets, or better – diverse equal-cost fleets of Ospreys, Sea Knights, CH-53 Sea Stallions, and two modern helicopters – US-101 and the Sikorsky S-92.[8] Secondly, the Marine Corps neither presents nor uses reliability data that so heavily influences the number available for flight operations. Why? Because the complex, very unreliable MV-22 compares unfavorably with helicopters – the CH-46E Sea Knight, the old CH-53 Sea Stallion, the new Sikorsky S-92, and the older Lockheed US-101 helicopter.[9] The first OPEVAL evaluated the relative reliability of the MV-22 and that of the CH-53, to find that the Osprey was only *half* as reliable (that is, half as flyable) as the CH-53 heavy lift helicopter. This requires doubling the fleet of MV-22s to perform their mission to the same reliability. These are test results! To call the aircraft more maintainable (and hence more reliable) is to be completely disingenuous.

How do the other parameters – speed, lift-capability, range, and deployability compare?

Speed in Flight – There is no question that in the aircraft mode, with engines aligned with the flight path, the Osprey is faster. The maximum speed of the Osprey at 20,000 feet, *alleged* to be 300 knots, would essentially be twice the maximum speed of helicopters, which occur nearer 10,000 feet. In the June OPEVAL, the Osprey demonstrated only 240 knots at 3,000 feet. Combat Marines and war materiel are transported essentially at sea (surface) level for survivability. There, the disparity in **cruise speed** is considerably less. At sea level, helicopters cruise at 150 to 180 knots; the Osprey at 220 knots, a marginal advantage. *Normal-cruise speeds, rather than maximum speeds, are the relevant speeds.* Aircraft are seldom flown at their maximum speeds for many reasons. Further, the Osprey can not operate above 10,000 feet with human or mammalian cargo because the cabin lacks the oxygen and pressurization necessary to sustain the proper quality of life. But the main point never presented by the USMC is that the correct evaluation of speed lies not in the genteel sport of racing between two points without a load, but in transporting men and materiel into combat arenas and returning. This means adding the time it takes to get the aircraft readied for flight while still aboard the ship, the time to load the aircraft, to take off, to form the attack force, to transit to the target area, then to slow, land, load return elements, and return to the ship. All this at sea level or ground level, for maximum survivability. The flight distances from ship to shore are relatively short – the order of 25 to 50 miles.[10] The time spent in transit is thus a small part of the overall mission duration. Further,

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[8] The only source for these comparisons is the Riccioni Report to SAFFM.

[9] The Sikorsky S-92 is a very capable, modern, low-cost US helicopter considerably lighter than the Osprey. The US-101 (the Augusta-Westland EH-101) navalized helicopter designed by Italy and Britain, if found acceptable, is to be built under license by Lockheed in the US.

[10] Source: Official Marine Corps briefings describing their operations in "Assault from the Sea." But to be fair, I did my analyses over a broad spectrum of distances, from 25 out to 120 miles The data reveal that the materiel loads and combat Marines that can be transported over an operational period are greatly reduced with increased distances from the shore. Large distances are undesirable because they increase the time that the ships (the V–22 carriers) are exposed to enemy attack.

since the Osprey has the smallest cabin of any competitor, it is the most difficult to load, requiring additional time. Zero speed averages badly with cruise speed. Quantified analysis reveals that its 35 percent cruise speed advantage is largely washed out by the interface actions and by its unreliability. The Marines should be dividing the distance by the total mission time to determine the speed of the operation. These data, never presented by the Marines, will be provided. But there is more to the problem, as will be shown.

Lift-Capability – These comparisons suffer from distortions similar to those of speed. The Osprey, which is three times heavier, allegedly lifts three times the maximum load of the much lighter, older, cheaper, smaller CH-46E. That represents no gain in effectiveness or efficiency. Besides, these are *maximum load* comparisons. Transports are not always loaded to their maximum weights. They frequently carry personnel and light, bulky equipment, unless loaded with ammunition, petrol, and water. Unmentioned is that the cabin of the much smaller and lighter CH-46 is 70 percent larger by volume, and the floor area is 50 percent greater than that of the MV-22! Two USAF test pilots and one Marine test pilot told me that the Osprey could *properly* seat 24 fully-equipped combat Marines – the brochure number. But OPEVAL-1 revealed that the correct number is only 18.[11] Again, a proper comparison is the relative capability of comparable fleets to transport men and materiel from ship to battle area and return over a nominal operational period, taking maintainability (reliability) into account. For example, at equal cost even the obsolete CH-46E fleet is 80 percent more effective; the CH-53 fleet is twice as effective; and the new smaller, cheaper, modern US-101 helicopter fleet is three times as effective.[12] [13] This, at ship-to-shore distances from 25 to 100 nautical miles.[14] The USMC only quotes the three-fold greater lift capability without stating how far that load will be carried, leading the non-cognoscenti to believe (erroneously) that it is three times better. So much for lift capability and the mantra spin.

There remains the last element of Mantra 1 – **range** – or, better, because it is more meaningful – **payload-range**. *Range* (one way flight)**,** and *radius-of-action* (two way flight, out and return) have meaning only with a defined payload.

In the specious comparison of the Osprey with the much lighter, obsolete, very-low-cost CH-46E Sea Knight, the Osprey can indeed fly about 2.5 times further, but not the five times stated in the mantra. Yet, it is in this range that the Osprey *should* shine – because in the aircraft mode, its lift for the same drag force (aerodynamic efficiency) is twice that of modern helicopters. However, Breguet's range equation has two numbers that dominate the range of aircraft: lift-to-drag ratio (L/D) and the fuel fraction (FF) – the weight of fuel divided by the weight of the aircraft at take-

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[11] I assume the test pilots didn't know.

[12] These data are based on *cost numbers* in my report to the USAF in 2002. The USN and USMC program managers complained that my cost numbers were too high, but the *alleged* discrepancy will be discussed later in this paper.

[13] These comparisons are found *only* in the report by Riccioni (Riccioni Report). This was noted by DOTE's Honorable Phil Coyle.

[14] In apparent attempts to game the helicopters out of the competition, the Osprey is constantly portrayed operating at ship-to-shore distances greater than 200 miles. Yet Marine Battle Commanders desire to maximize the load carried on each trip by sailing as close to land as possible. Marine Mission Plans reveal the distances to be routinely 25 to 40 nautical miles. Maximum loads, and hence transport capability, decrease rapidly with increased mission distance.

off. The designers of the US-101 helicopter increased its fuel fraction (effectiveness) sufficiently to compensate for its lower lift-to-drag ratio (efficiency). The CH-53 can always carry enough fuel to give it a greater range than the Osprey.[15] Proper analysis involves *comparable loadings.* Proper evaluation considering fuel reserves reveals that the *troop-carriage radius* of action of the MV-22 and the cheaper, *smaller*, equal carriage EH-101 helicopter are precisely equal out to radii of 200 nautical miles. Competent Navy tests revealed that the CH-53 Sea Stallion carries twice the weight of the Osprey to any range![16] Mantra 1 is mostly fiction!

Mantra 2 is equally specious: it sounds good until analyzed. For instance, the maintainability has been reviewed and refuted. The maintenance problems are both many and unique, and have kept the aircraft from routine operation for more than five years. **Causes** – The aircraft vibrates excessively, breaking things and creating its own foreign objects to damage it in flight. Its hydraulic system uses titanium tubing and operates at an extremely high 5,000 psi pressure. Titanium is stronger and lighter than steel, but it fails more frequently from vibration fatigue. Continual checking is required to detect possible fractures. Titanium is incompatible with the salt in a sea environment. With rupture or combat damage, hydraulic spray released into the cabin is deleterious to human life. The hydraulic system cannot be changed to steel and the conventional 3,000 psi pressure for reasons of space limitations in the engine nacelles – a seemingly incurable problem. The software controlling the aircraft with its many operating states frequently malfunctions. The aircraft could not fly in clouds for lack of anti-icing equipment on its rotors and engine intakes.[17]

Survivability – Helicopters are much more survivable in combat operations than the Osprey.[18] Survivability in proximity to the enemy lies not in speed and altitude, for none can outrun surface-to-air missiles. Enemy gunfire solutions are not defeated by speed, but by ability to turn – pulling Gs. The Osprey is much less maneuverable than are helicopters that maneuver agilely in and around trees and hills, and down valleys to survive. This is especially true with the Osprey in the helicopter mode because its Gs for maneuvering are unacceptably low. A wealth of flight test data proves this.

The Osprey's "fast-roping" (sliding down a rope using heavy gloves and friction to control their speed of descent) is very slow. Marines being disgorged by "fast roping" can only be released two-by-two for reasons of center of gravity control, and *only* from the rear ramp, and *only* after the leading pair hits the ground. The Osprey must hover at heights the order of a hundred feet, because the powerful downwash may injure the landing Marines. The Osprey must remain stationary in plain view above most trees, if any, remaining vulnerable to all forms of enemy fire for three to five minutes. Helicopters, however, can disgorge four to twelve Marines at a time in rapid sequence, out the sides and rear, from low altitudes in and among the trees, in approximately 30 seconds, vastly reducing their period of vulnerability. Helicopters can open

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[15] The turbine engines of the MV-22 and the US-101 are comparably efficient and don't affect the range comparison.

[16] Official US Navy data, *Naval Expeditionary Logistics: Enabling Operational Maneuver From the Sea*, Fig. D. 4, p. 82.

[17] This deficiency has recently been remedied. Curiously, the Ospreys selected for the OPEVAL were not equipped with anti-icing equipment. Reason? The equipment adds undesired weight to an aircraft already so overweight that it flagrantly failed its load carriage/radius-of-action tests. It will take time to modify the existing fleet to operate in icing conditions. Clearly, this routinely-necessary feature should have been incorporated from the beginning.

[18] And as will be revealed, the Osprey is much less survivable in *peacetime* operations, as well.

their side doors to let Marines jump and roll directly to the ground from altitudes of a few feet at very slow speeds, without landing and taking off again. This is the preferred method of disgorgement when vulnerable to enemy action. The Osprey can't do this for the deleterious effects of its high-speed downwash. It must land to disgorge, increasing its time of vulnerability.

Another problem is auto-rotation in the case of complete power failure. *Every helicopter* must demonstrate the ability to make safe power-off landings with a full load *by autorotation.* Auto-rotation converts descent energy into rotor rotational energy, which can then be transformed into slowed descent and a safe landing. The Osprey with its small diameter and low inertia prop-rotors cannot store sufficient energy to achieve a safe landing.[19] Many helicopter crews and passengers were saved in Vietnam by recourse to auto-rotation. Given the failure of one engine, the Osprey can fly with the remaining engine powering both rotors. Granted, complete power failure is not likely in peacetime unless in icing conditions or in case of fuel exhaustion, but it is vulnerable to complete power loss in combat. All vertical lift aircraft are.[20] Then the Marines claim that the aircraft can glide to a safe landing on its belly. For reason of its very small wing, the Osprey's glide speed is extremely high and a crash-landing on unprepared surfaces will generally be catastrophic. Clearly, when in proximity to the enemy and facing the risk of battle damage, it is much less survivable than are helicopters. Conservatively, considering all the factors, helicopters are five to ten times more survivable in combat operations. Once, there were plans to mount a multiple barrel rapid-fire Gatling gun on the Osprey to suppress enemy fire. This has not yet happened because of the attendant vibration, center of gravity problems, and the undesired weight it will add. A remotely-aimed gun firing system will reduce the useful load by another 1,000 pounds, almost 10 percent. Its load lifting capability is already deficient, being *half* of its KPP (minimal standards). Defense suppression will likely be denied the Osprey.[21]

The Osprey does appear to be superior in one aspect of survivability. In the propeller mode, it has a significantly lower sound signature than do helicopters. When in the vertical lift mode, it is comparably noisy. But again, its reliability and lift performance problems intrude. *It takes more Ospreys to fulfill a lift requirement to a similar probability of success as that of helicopters.* Increased numbers increase the *operation's* signature.[22] Required numbers must always be considered. (Numbers, numbers, numbers.)

Self-Deployability – I gained considerable operational experience while managing deployments of F-4D Phantom jet fighters from Kunsan and Osan Airbases in South Korea to Vietnam. Typically,

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[19] The auto-rotation deficiency was finally admitted, but only after years of continual denial. A three star Marine general (name repressed, but recoverable) once actually testified to Congress that the Osprey *was considerably better at auto-rotation* than helicopters. Why misinform? Now, of course, this dangerous limitation goes unmentioned.

[20] The military lost more than 1,800 helicopters in the Vietnam War, most of them in the destination landing areas.

[21] For revelation to men-on-the street and Marines alike, one should view the intensive combat operations in the excellent movie *We Were Soldiers* based on the book We Were Soldiers Once and Young by Moore and Galloway, 1992. It portrays the Battle of Ia Drang, the first large-unit battle of the Vietnam War. It reveals what the Humble "Huey," the UH-1 helicopter, did for the 7th Cavalry Regiment in active combat, things that the Osprey cannot do. Hueys tasked with an attack role were outfitted with rocket launchers, grenade launchers, and machine guns. Those used for troop transports had door gunners. They were properly engineered for battle and combat support.

[22] Vertical lift aircraft can never be considered stealthy across the full spectrum of their many signatures. They gain stealth by hiding, by tight terrain following and flying between structures, trees and whatever. But, one-on-one – the usual inadequate comparison again – the Osprey in the conventional airplane mode is quieter than helicopters.

one gets a hurried request from an embattled combat wing commander to rapidly provide a number of suitably-configured aircraft. The aircraft configuration must normally be altered for the embattled wing and for the voyage. Then they must be put into the best possible maintenance condition and flight-tested. Once readied and fueled, they are launched. At their destination, aircraft that suffered in-flight breakdowns must again be readied for their missions. Since modern helicopters like the Sikorsky S-92, the US-101, and even the old CH-53, can be loaded with sufficient fuel in the cabin to match the Osprey's range, only its (circa 35 percent) cruise speed advantage remains. It is significant and may not be ignored. Yet, time saved in flight can easily be lost by the Osprey's greater maintenance requirements on both ends. And, for reasons of reduced reliability in flight, it is propitious to send additional Ospreys as spares. Using only *flight speed* to measure deployability is far too simple minded, especially when the ranges of the Osprey and helicopters are comparable.

It has now been shown that both Marine Mantras are propaganda – distortions and disinformation to gain a specific end – rather than effective criteria for the purchase of new aircraft. Worse, they also constitute self-deception. Marines actually believe them.[23]

But there is much more! The combination of conventional aircraft flight with the helicopter mode *appears* to provide a degree of versatility, but gives rise to unforeseen difficulties. **One**, the prop-rotors cannot be optimized to be both propellers and rotors, so they are compromised. They are degraded propellers and non-optimum rotors. This is well understood, but is never admitted. **Two**, rapid, steep descents near the ground with the aircraft settling into its own downwash generate a complex phenomenon known as the *Vortex Ring State* (VRS). It results in a precipitous loss of lift on its rotors. This dreaded phenomenon (familiar to helicopter pilots, also) makes a side-by-side lifting mode aircraft vulnerable to loss of control. One rotor always suffers loss of lift first, normally surprising an unsuspecting, busy (embattled) pilot with an uncontrolled roll and a dropping of the nose. Recovery from inverted flight is difficult because it normally requires more altitude than the aircraft has available. Twin Rotor helicopters having their lift centers distributed along the longitudinal axis do not roll with onset of the VRS. Their forward rotor gets VRS first so its nose drops and they immediately fly out of it with the resulting increase in forward speed and little loss in altitude. The Osprey's pernicious departure from control has been thoroughly explored by highly-qualified contractor and Marine test pilots. The best resolution is *avoidance* of the now completely-known dangerous flight domain of descent rates and speed. Yet, *the combat requirement in proximity to the enemy is to descend steeply and quickly, land, disgorge, and depart*. Quickness is denied Osprey pilots. As an example – after the first (failed) OPEVAL in 2001, the V-22 was (wrongly) approved for operational testing carrying live Marines. The test flight of two V-22s flying in formation to a destination airfield in the Western US resulted in a horrible accident. Both aircrews (pilots and copilots) were among the most skilled and experienced pilots flying the V-22. Despite being familiar with the VRS phenomenon, the lead pilot – under pressure to land at his destination airport before darkness – made a steep descent at a slow airspeed to approach the landing site. The second aircraft flying formation on the lead, entered the forbidden VRS speed-altitude zone, suffered a stalled rotor,

[23] For proof, read the Marine Mantras in articles about the Osprey in recent issues of the *Proceedings* magazine published by the US Naval Institute. This is arguably the most prestigious military magazine in the world, but their independent editors are properly open-minded and cannot be held responsible for misinformation fed them by the establishment.

lost control, and crashed. The crew and the 18 Marine passengers were all killed. This accident, along with others, resulted in a moratorium on using live Marines as cargo, and eventually resulted in a one-year moratorium on flight testing.

It is interesting, and undesirable, that the Osprey is sensitive to both center-of-lift and center-of-gravity changes purely because its lift centers are distributed along the lateral lift axis. Its nature is to "teeter" both laterally and longitudinally – an unstable condition. Twin rotor helicopters do not have either difficulty, simply because their lift vectors are distributed along the aircraft centerline – a stable configuration. The Osprey's problem is generic to all tilt-rotor aircraft. The pilots and control software make it flyable. If both are good and in good working order – it flies quite well. However, because of the complex nature of the *convertible* V-22, software malfunctions have generated repeated problems, emergency landings, and a few accidents.

The US military once attempted to rescue some 53 embassy members held hostage in the Embassy at Teheran, Iran in 1980. Marine officers, especially generals and colonels, constantly state that had the Osprey been available for the hostage recovery operation *"Eagle Claw,"* it would have been a consummate success since the point where the disaster occurred (Desert 1) would have been overflown. What a reprehensible insight into the event! The only reason that the airfield at Posht-e-Badam in the middle of the Dasht-e-Kavir Desert (built surreptitiously by the CIA years before and code named *Desert 1*), was not overflown during *Eagle Claw* was that the Marines injected themselves into the operation merely to get "a piece of the action."[24] A formal Marine briefing, widely distributed and accepted, portrays *two* Ospreys transferring 130 Delta Rangers to Teheran and extracting some 180 hostages and Rangers in an eight hour mission – a fantastic feat since two Ospreys can seat only 36 Rangers. The planners determined that 4 RH-53s (seating 45 each) were the minimum and for reliability reasons wisely opted for eight RH-53s. The Admiral Holloway Commission determined that minimum number should have been 10, with 12 the recommended number. Based on *carriage* and *the same probability of accomplishment*, the comparable required transport fleet is 30 Ospreys, not two.[25] There were other comparably bad errors in computing the mission times and the refuelings required.

The non-Marine planners allowed inexperienced Marine pilots to displace experienced, competent USAF crews that were intimately familiar with their USAF RH-53, its quirks, and its capable but complex navigational system. The displaced USAF pilots were skilled in refueling the aircraft in the air. Despite the weeks available for practice and skill development, the Marines had to resort to archaic *pilotage* for navigation at night over a featureless desert, and landed at Desert 1 because of their inability to learn to refuel the aircraft in flight. Yet the Marines blame the helicopters! They have yet to understand the failure, despite a competent postmortem analysis by the Admiral Holloway Commission describing many of the errors. [26] [27] This

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[24] To fully appreciate this hair-raising, ill-fated adventure, read Chapter 4 of *Military Incompetence: Why the American Military Doesn't Win*, by Major Richard Gabriel, U.S. Army, Noonday Press, NY, NY, 1984. For a more complete analysis of the full lack of insight of the Marine Corps in this exercise, read the Riccioni Report.

[25] Riccioni Report. p 38.

[26] In all fairness to the Corps, the mission would have failed anyway. "It was written." The overall mission planning and practice sessions were unbelievably egregious. Indeed, we must be grateful for the Marine incompetence – had the mission progressed further it would have resulted in an even greater disaster. As it was, the disaster was bad enough to depose President Carter.

fascinating but tragic episode, a classic example of egregious planning and flawed practice to end in incompetent execution and disaster, should be studied by all, especially by the Marine officer corps.

High-ranking generals have frequently lauded the high-altitude performance of the Osprey in their testimony to Congress. They confound the facts. The Osprey can fly at twice the altitude of helicopters (over 20,000 ft), but it can't operate there.[28] It cannot carry mammalian cargo to those altitudes. It cannot carry significant loads to high altitudes because it cannot land and take-off there. Helicopters are considerably more efficient at high altitudes for reason of their much lower rotor disk loading. The US Navy has all the data in their NATOPS flight manuals, revealing the relative inferiority of the Osprey in high altitude operation. Yet the flow of misinformation continues.

Once cost is allowed to enter the analysis, the Osprey falls apart. There are really three dimensions to cost analysis – the cost of acquiring the fleet and its operational cost, the capability of the system independent of cost, and the cost-effectiveness of the system. This last item measures the efficiency of the system. The analysis in the report to the Air Force[29] reveals that *all helicopters are essentially three times more cost-effective than the Osprey, regardless of the mission* being flown – combat troops, news personnel, or cargo.[30] If the Osprey can do something important that helicopters cannot, it is reasonable to ignore its cost at times, unless it is obscene (which it is). But in this case, it is *the high-cost system which has the deficiencies*. Its purchase makes sense *only* to dedicated Osprey proponents.

And there is more. The Air Force decided years ago to give up a critical traditional role for its V-22s – that of picking up downed pilots. Despite the Osprey's speed, its pilots have difficulty landing it in desert sands, in snow, and in areas with vegetation debris because of its high-speed downwash (plumes) with a hot jet wake at its center.[31] Landings and take-offs in such conditions are usually done on instruments for the cloud of sand or debris or snow that it generates obscures the pilots' view of the landing surface. The high-speed downwash will not allow routine pickups of people stranded on rooftops, in boats, or in the sea. The Osprey is likely to cause snow slides

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[27] Actually, Ospreys were available, lying fallow. They had been in low rate production during development for some 15 years. But they were so trouble-ridden that no one thought to use them.

[28] Geese have the same problem. They have been seen overflying Mount Everest, but should they land, they die instantly for lack of oxygen and the sub-zero temperatures. They can fly at those altitudes, but cannot land or take off there. The geese know it, for they never land there; nor do they ever misrepresent their ability to do so.

[29] Riccioni Report.

[30] An interesting episode occurred while briefing the analysis to the military. My costing, necessarily done independently of the *restricted official* numbers, was estimated to be 50 percent greater than the cost quoted by the Navy System Program Office to itself, to the services, and to Congress. The SPO accused me of using incorrect and inflated cost data. About a year later, truer, more accurate costs were finally *officially released* which were 60 percent higher than my numbers! I had erred in being far too conservative. **The Osprey is much worse than I reported it to be!** To be specific, the original official SPO unit flyaway cost of the Osprey was allegedly $40M. I deduced $60M. The (internally quoted) "real cost" then was $74M. The current SPO quote is $85M. The forecast costs for 2006 and 2007 are $118.5 and $127M, respectively. Which is the correct cost? Disingenuous costing is a way of life in the DoD. It is the public that loses, but it is only tax money.

[31] The Osprey used to ignite debris on landing. An early promotional demonstration with the Osprey landing on the Pentagon grounds precipitated grass fires and turned into a debacle. This deleterious problem has been ameliorated.

in hills and mountains endangering the victims. But no matter – for some obscure reason, attempts to design and install a winch for picking up and lifting downed personnel have failed thus far. The US Air Force gave up on using the Osprey for this critical mission, because of its unsuitability: it will use helicopters instead. This decision has yet to impact the USMC. It is now clearly evident that new, modern helicopters must be procured to fill in the capability and performance shortfalls of the V–22, generating even greater cost.

Why does the Osprey compare so unfavorably with modern (and even the older) helicopters? The deficiencies demand explanation.[32] Are they errors in execution? Or deficiencies generic to the concept? The first can possibly be fixed; the second cannot – the very concept of tilt-rotor aircraft is basically flawed!

Several fundamentals contribute to its mal-design: Excessively high disk loading, side-by-side lifting, high weight of the system, and its necessarily small cabin size. The design constraints necessary to achieve the Osprey's unique *convertability* place the value of tilt-rotors in doubt.

Disk loading is the average weight that each square foot of rotor area must lift when operating in the vertical (helicopter) mode. Disk loading for vertical lift aircraft corresponds to *wing loading* for conventional aircraft in some ways, because the rotor is a rotating wing. The higher the disk loading, the greater the engine/prop-rotor system must work, and the faster the speeds in the downwash plumes must be to provide the necessary momentum change for lift. Basic physics. The side-by-side placement of the engines with rotor radii limited by the presence of the fuselage and the need to be compatible with ships, result in a disk loading for the Osprey more than twice that of comparable helicopters – bad! Worse, this cannot be resolved! Basic geometry. Also, the downwash plumes from rotors above the wing impinge on it, pushing it down and further reducing its lift capability. The disturbed, high-speed downward flow of air distorted by the wing results in complex, unpredictable, turbulent, high velocity domains underneath the Osprey. This is one reason it is unfeasible to disgorge Marines from the side doors. Fast roping from low altitude leads to injuries. Even from "high hover," the Marines finally touching the ground are advised to lie down or be blown down. Only the rear ramps are available for fast roping. With its sensitivity to its center of gravity position, the need to control it forces the Marines to progress slowly to the rear. This means slow fast-roping, and increased vulnerability. The USAF regards fast roping from the Osprey a do-able stunt, but not a practical way of disgorging personnel. So the V–22's convertability causes the loss of two modes for rapidly disgorging personnel. It must land and take-off to load or unload men and materiel – increasing its vulnerability to enemy action. This is a great disadvantage in light of its visibility problems in operating from unprepared surfaces. High disk loading is the culprit. It is also the major cause of its degraded high altitude performance, much as a high wing loading degrades the high altitude capability of a conventional aircraft. The Osprey's excessively high disk loading is generic and unresolvable.

The V-22's excessive weight is partly the result of the mechanism necessary to rotate the nacelles. Heavy cross shafting connecting the widely-separated rotors is necessary for synchronization and control, and to power both rotors given a single-engine failure. This weight reduces the load-lifting potential and lowers the fuel fraction, degrading the Osprey's range. Its necessarily

[32] A more comprehensive explanation and analysis is available only in the Riccioni Report.

compromised prop-rotor means less lift capability and less efficient propulsion in forward flight. The concept has some unresolvable problems. *The point – tilt-rotor aircraft can operate, but not efficiently*.

This information must be quantified to reveal the full deleterious impact of convertability.

Some Quantified Comparisons – The ancient CH-53 helicopter is an excellent basis for comparison because it is old in state-of-the-art, but has essentially the *same empty weight* and the *same power* as the Osprey. Note the numbers provided below and their sources.

1. The Osprey carries only half the load of the old-state-of-the-art CH-53 to the same range.[33]

2. An official US Navy Study measured *the transport effectiveness* (speed x payload = ton-miles per hour) of both aircraft to find that, "Despite the higher cruise speed of the Osprey, The transport effectiveness of the CH-53 is 1.66 times greater than that of the Osprey."[34]

3. In transport cost-effectiveness, the old CH-53 is 2.3 times as cost effective as the V-22![35] [36]

The different official studies with their differing but related parameters agree and fit neatly together. They tell the same story, a story missed by all the pundits who did no quantified analyses![37] A major, general flaw of tilt-rotor aircraft has been revealed – the Osprey is grossly inefficient as a transport in addition to being ineffective in key Marine missions.

Tilt-Rotor technology is a step backward in effectiveness.

Summary – It is clear that the Osprey is **more dangerous** (omitted from the mantras); **less maintainable** (in contradiction to the mantras); **less efficient in lifting** (hidden by the wrong comparison); **much less survivable in combat** (in contradiction to Mantra 2); **deficient in load lifting** (in contradiction to Mantra 1); **less versatile in mission capability**; **has a considerably lower altitude capability**; and **will less ably serve the country and the Marines than can**

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[33] Study by the unofficial Red Ribbon Panel. "Technical Comparison Tilt Rotor and Helicopter Performance: Based on Published Performance." The Red Ribbon Panel, led by Col. Harry P. Dunn, USAF (Ret.), is a group of pilots and engineers who have challenged the Osprey on technical grounds.

[34] *Naval Expeditionary Logistics: Enabling Operational Maneuver From the Sea.* National Academy Press, 1999. page 82, Fig. D.3.

[35] Formal definitive report to the USAF Secretary for Financial Management (Riccioni Report) 2002. Neither Secretary Michael Montelongo, nor his Deputy, Bruce Lemkin, understood it. However, the thirty staff members *in situ* from the USAF, the Navy SPO, and Marines did. The staff raised only two criticisms: one, that I didn't use the maximum speed ratios in the analysis; and two, that my cost numbers were excessive. Both criticisms have been proven specious by history.

[36] These cost effectiveness numbers were based on my estimates of cost. They are conservative, and should really be increased by 40 percent making the obsolete, ancient CH-53 3.2 times better than the Osprey. But the Osprey and its SPO's credibility have suffered enough — I prefer to remain conservative.

[37] The *pundits* include captains from industry, an MIT professor of aerodynamics, experts at NASA Ames, and many more. A rhetorical but vital question — *Why didn't they use analysis to understand the Osprey?* They were certainly capable of doing so. Or were they?

modern helicopters.[38] That it costs more is a gross understatement. And its cost will be increased by the need to buy new helicopters to make up for the Osprey's inabilities.

The US Navy cannot be enamored of supporting V-22 operations. With half the reliability (flyability) and half the transport effectiveness of helicopters, many more V-22/helicopter carriers will necessarily be placed at risk. Four times as many?

Were the Osprey even a shadow of its claims, it would long ago have been selected to transport the president and his staff in emergencies. It was evaluated for this function three times over the last five years and found wanting for reasons unrevealed, but clearly evident.

With this background – in an attempt to right this seemingly unrightable wrong – I will run where brave analysts dare not go: Predicting the future for an Osprey-equipped Marine Corps.[39]

I predict that:

1. To avoid additional bad publicity in peacetime, the Corps will treat the Osprey like a cream puff. USMC pilots, normally aggressive by training and nature, will avoid using it to its full potential – by edict. **But despite this, the V-22 will generate some novel problems.**
2. In the course of battle, the full combat spirit of Marine pilots will challenge the boundaries of the Osprey's operational domain to serve their embattled fellow Marines. **Then the unnecessary losses will reveal themselves.**
3. **The Osprey will serve the Marines much more poorly** than can modern helicopters.
4. **Routine operations at sea will result in increased losses** (compared to helicopters).
5. **Modern Helicopters will**, because they must, **be bought to cover the shortfalls in USMC military capability**.[40]
6. Finally, given normal operations in peace and in war, **the loss rate of the Osprey will exceed that of the "Widow Maker," the AV-8B Harrier, by 10 - 30 percent.**

The Marines, so long committed to making the MV-22 Osprey its major transport, will soon be equipped with it. The Corps persevered and won this three-decade long campaign. Full-scale production is finally underway. *But it will be a pyrrhic victory*. The next few decades will establish the validity of this review – or my errors in judgment.

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[38] There must be something entertaining in all this dismal news. And there is. What could possibly be worse than a flawed *twin-engine*, tilt-rotor aircraft concept? A **four-engine** tilt-rotor aircraft, with wings in tandem and engines tilting on all four wing tips. The total energy in the downwash would be doubled. Assuming that all four engines can be controlled, the sensitive center of gravity problem will be eliminated. The control options and freedoms become fascinating. Shipboard operations will be "most interesting." It is under consideration by the avant guarde elements of the USMC, of course. The lobbying has begun. But this dream can reach fulfillment only in the distant future. The question is whether a Marine Air Force will be there to fly it.

[39] What permits taking the risk of prediction? – Knowing and understanding the dynamics of the situation.

[40] This prescient statement found in my report to the Secretary of the Air Force for Financial Management was ignored by the services. Now, one increasingly hears of this need among DoD personnel. Indeed the acquisition is underway. The Marines and Sikorsky are cooperating on an improved version of the CH-53E, the CH-53K, to make up for the shortfall in the Osprey's transport ability. It will take care of many other problems also.

I leave it to the public and to history to decide who is right.

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