JOINT SEMI-AUTONOMOUS AIR WEAPON SYSTEM

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SUMMARY

The Naval Air Warfare Center has investigated the idea of a semi-autonomous air weapon system that could be used in a lethal role. While such a system appears to be a natural continuation of military aviation we are just now beginning to appreciate some the nuances inherent in such a system.

In our approach we will not just "put weapons on UAV" or "take the pilot out of cockpit" either physically or mentally, or produce "more capable one-time use weapons." Rather our proposal for JSAAWS is for a total weapon system designed for the tasks at hand.

There are two lessons to be learned from history. The first lesson is that a new weapon concept such as JSAAWS must be designed for its intended application and not be just a retrofit of an existing system. The second lesson is that we need to develop JSAAWS in an orderly fashion, we need to walk before we run.

Potential advantages of a JSAAWS for a Naval Expeditionary Force include increased survivability, decreased cost, increased lethality, via increased OPTEMPO and the ability of a JSAAWS to act as a force multiplier, and the ability to show a more aggressive presence when first-on-the-scene.

In whatever role it plays, JSAAWS must be cost effective when compared to manned aircraft and one time use 'smart' weapons. One major contributor to cost savings would be greatly decreased operations and support costs due to vastly decreased flying hours. For example, life cycle cost could be reduced by 28% just from reduced flight hours.

We have looked at several missions for a JSAAWS, some of which are more suitable for a JSAAWS then others.. These are: SEAD (the initial mission of choice for the operational community), Battlefield Support / Simplification, Armed Recce, ASuW in the Littoral, supporting Operational Maneuver...from the Sea, Counter Cruise Missiles, Offensive Counter Air, and Defensive Counter Air.

Three notional system design concepts have been defined that cover all of the missions for a Naval Expeditionary Force. The high-end concept is the Highly Maneuverable Lethal Vehicle, which will be described in detail in paper 4 of this Conference. This would be a multi-role system for both air-to-air and air-to-surface missions. The air arsenal ship is a concept that has been put forward by the US Air Force. It would have limited air-to-air and air-to-surface roles. The low-end concept would have capability in a limited, but operationally significant, set of air-to-surface missions, CAS, BAI, AI, SEAD, Indirect Fires. Included in this mission set is a significant percentage of the total targets for tactical combat aircraft.

1 INTRODUCTION

Over the past several years there has been steadily increasing interest and activity in the area of pilotless systems that could do more than surveillance. These putative systems have appeared under various names: Weaponized Unmanned Air Vehicles (WUAV); Tactical Unmanned Aerial Vehicle (TUAV); Unmanned Tactical Aircraft (UTA); Uninhabited Air Vehicles (UAV), where the term uninhabited means unmanned but still controlled to some degree from outside the cockpit; Lethal Unmanned Vehicles (LUV); Lethal Uninhabited Combat Air Vehicles (LUCAV); Unmanned Aerial Vehicles (UAV, again); Unconstrained Maneuvering Air Vehicle (UMAV). The constant thread here is that the system is defined by what it is not, i.e., not manned by a pilot.

This situation is analogous to that which developed when the automobile was first in use. When the automobile was first invented it was called a horseless carriage, as this was the only way to describe its essential quality, i.e., it carried things over land without a horse. The automobile is much more than a carriage without a horse, it is much, much more. However it could only be described in the reference frame that existed, and in that reference frame it could only be described at the time by what it was not. The same thing is true for JSAAWS, at the moment we describe it by what it is not.

While this is as much a matter of semantics as anything else, words do carry with them meanings. Thus to call the system unmanned or uninhabited carries with it the definitions that people have given to these words in this context. We could try empty or vacant, but that would give rise to entirely different pictures, so we go with joint semi-autonomous air weapon system (JSAAWS). It is difficult to describe something completely new using words that bring with them pictures and ideas from

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existing things.

We believe at this time we can start to define an uninhabited system by what it is rather than by what it is not. The primary attribute of this concept is that it is to be designed and built using a weapon philosophy. This differs from the approaches currently used to produce aircraft and UAV. Explicit details on what this means will be given later. The major difference between this concept and current 'smart' weapons is that the most expensive part of this weapon system is recoverable and reusable. We do believe that when executed correctly this approach will provide a discontinuous change in the way we fight. It will be a jump ahead.

Possible mission roles are being developed for JSAAWS. The fundamental idea behind such a system is to maximize the survivability of pilots and optimize the system cost effectiveness, by providing the option to use a cost effective JSAAWS instead of a manned vehicle, or a one-time use 'smart' weapon such as a cruise missile, thus allowing pilots to avoid the most dangerous, dull, and dirty parts of the battlefield, yet retain the real-time tactical mission flexibility that is the hallmark of TACAIR.

There are several trends, that taken together, are drivers for initiating a study of such a concept now. Defense budgets are likely to continue to decrease, or at best remain uncertain, over the next several years. The Naval Services and the rest of the DoD will continue downsizing. While this trend continues it remains a matter of national security to maintain, or increase if feasible, our capabilities. Whatever we do, threat spectrum we face is becoming increasingly lethal and widespread. At the same time, particularly in conflicts that the American people do not see as directly related to our national survival, public tolerance is decreasing for any casualties, military or civilian, hostile, neutral, or friendly.

Any solution to this problem must be cost effective relative to alternative approaches, and must integrate with and the existing/proposed force structure.

Our approach has been to look in an iterative fashion at valid mission roles, general issues and requirements, notional operational concepts (at the mission and engagement level), and notional implementation concepts.

We have identified several general issues that must be addressed before a JSAAWS can be considered for operational use. Flexibility to retarget is important, as is positive combat identification (PCID) of ground targets. It will also be important to have well defined rules of engagement (ROEs) for accountability, and an over-ride capability to maintain positive control. Finally, it will be critical to establish operational doctrine for cooperative engagement with manned aircraft and other joint, coalition and allied forces. The JSAAWS must be integrated into the general communications network and contribute to overall battlespace awareness.

We have made one complete pass through these four areas and this paper and presentation report the results of that activity. At this point we have no single notion of what a JSAAWS should be. Rather we have a collection of ideas about different aspects of this system, some of which appear to be contradictory. However, as each iteration refines the thinking about these areas, we will pursue additional subjects, including technical and operational issues and technical deficiencies which can lead to investment decisions. We will also investigate the current state of technology and determine what demonstrations are both feasible and necessary. We plan for these later activities to lead to maturation of one or more specific concepts and the technologies required to implement them, and finally to development of the system.

2 LESSONS OF HISTORY

The JSAAWS concept is a natural evolution of trends in military aviation. Because of the ever-increasing pilot workload, one trend is that more and more functions on aircraft are being performed without the intervention, or in some cases even without the initiation, of the pilot. On the weapon side, the trend is toward more and more autonomy and multimission roles. Walleye, at the state of the art 25 years ago with its datalink and MITL guidance, can be compared to Tomahawk, with its long range and preplanned strike capabilities. The notional next step will expand the role of the weapon even more. A third trend is the proposed evolution of UAVs from unarmed reconnaissance to armed combat. These trends converge to a weapon system, or more likely, a family of weapons systems. It is in the space of this convergence that we want to look for concepts for JSAAWS.

Moving to a JSAAWS also continues the general trend in military aviation, and we can see history repeating itself.

When manned aircraft were first used, both for over-land and at-sea operations, their purpose was surveillance and reconnaissance. Commanders wanted to know where the enemy was and what they were doing. This was the equivalent of taking the high ground for information purposes so that maneuvers could be more effective. This is the current operational status of UAVs. We use them to locate troops and other potential targets. For manned aircraft this evolved into serving as spotters for artillery and naval gun fire. In addition to locating targets and providing that information to the gunners, manned aircraft could also feed back better information on where shells were landing and more rapidly correct firing solutions. They served a targeting and fire control function. UAVs are being used in that manner today, in support of field artillery. There is currently a lot of discussion, and some experimentation, using off-board assets to provide real-time-information-into-the cockpit (RTIC) and to designate targets using lasers.

In the history of manned aircraft, he next step was to incorporate on-board ordnance. The original ordnance was not very effective nor were the aircraft effective at delivering it, because neither had been designed and built for that purpose. This application for unmanned systems is also generating a lot of discussion and some experimentation. There are reports of one or two experiments in the Army and Marines using UAVs to drop bombs and shoot missiles.

The final mission step for manned aircraft was to deliver ordnance. This also led to the need to survive attack, both from other aircraft and from the ground. As the purpose changed so did the designs.

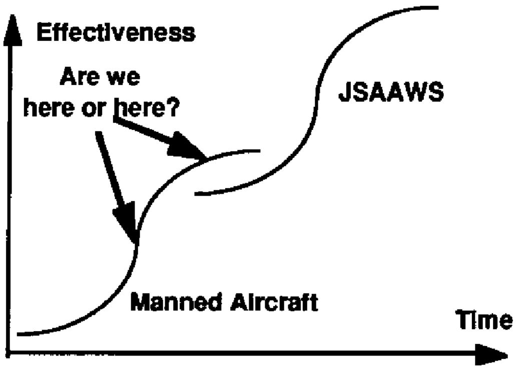
There are two lessons to be learned from this history. The first lesson is that a successful, effective JSAAWS must be designed for its intended application and not be just a retrofit of an existing system. The second lesson is that we need to develop JSAAWS in an orderly fashion, we need to walk before we run. As in any endeavor, when we try to change too many things at once we usually don't succeed. Thus we need to take a step-by-step approach and not try to do too much at first with JSAAWS. This ensures that any mistakes we might make don't cost too much because corrections are easier to make. But it also means that to have any significant capability when it is needed we need to start activities now.

One fundamental question that will be answered in the next several years is which way will we go with unmanned systems? Will we learn the lessons of history or not?

The notion of a JSAAWS, or something similar, is not new. There are numerous examples of unmanned vehicles carrying and releasing weapons going back many years. So we must ask ourselves two questions. Why should we be thinking about moving from manned aircraft to JSAAWS? and What is different now that makes us think we are ready to do this successfully on a routine basis? The answer to the first lies on the typical technology "S" curves shown in Figure 1.

If we think we are still on the steep part of the curve for manned aircraft then it will be more cost effective for us to continue to develop them . If we think we are on the flatter part of the curve then in order to make significant improvements in combat effectiveness we are going to have to leave the manned aircraft curve, even if the initial JSSAWS are somewhat less capable.

Figure 1. Technology Maturation Curve



Several technologies contribute to the ultimate success of a JSAAWS. The primary technology is the Global Position Satellite (GPS) system. This system allows both extremely accurate navigation and weapons delivery to a determined location to be automated to an extent that has not been possible in the past. The ability to control air vehicle flight via computers has been demonstrated in a number of "fly by wire" aircraft. This, coupled with the huge amount of computing capability that is available from modern signal processors and advances in intelligent decision making algorithms will allow these systems to fly themselves given only upper level commands.

3 UTILITY

Potential advantages of a JSAAWS for a Naval Expeditionary Force could occur in several area. These include, decreased casualties, increased survivability, decreased cost, increased lethality via increased OPTEMPO and ability of a JSAAWS to act as a force multiplier, and the command option to show a more dominating presence when first-on-the-scene. Below we postulate several possibilities, each of which is dependent on the JSAAWS having the increased capabilities specified. Which of these is attained will depend on what specific implementation, or implementations, of this concept actually come to fruition.

The ability to put an opponent's assets at risk in situations that would otherwise be highly dangerous for our warriors greatly increases the acceptable tactical and strategic options available to our commanders, both in limited warfare environments where loss of American warriors' lives is unacceptable, and in high-tempo warfare, where skilled pilots are an asset that is not replaceable in the near term.

In addition, the training required for such missions carries its own hazards and losses. Pilot survivability in training mishaps ensures their availability when needed for combat.

OPTEMPO and force multiplication could be increased in a number of ways. Being pilotless, time on station would be determined by hardware issues such as refueling capabilities and mean flight hours between operational mission failure (MFHBOMF). On the ground, turn-around times might be decreased if there were no sub-systems devoted to the pilot. If JSAAWS is used in CAP-like missions then pilots can be more available for missions that require human presence. Using a JSAAWS could reduce the need for SEAD, because, depending on design specifics, its unmanned nature could allow much more aggressive and survivable nap-of-the-earth ingress, or it could be smaller and less observable, or it could out-maneuver threat missiles, or any one of a number of other attributes could lead to greater survivability against threats. This would allow urgent targets to be attacked as needed, and SEAD would be performed only when needed, such as before manned aircraft are used in a particular area. A highly survivable JSAAWS that could get in close enough to the target and had adequate flight control, weapons release capability and targeting information could use abundant, simple ordnance, such as guns, rockets, and dumb bombs. This would mean that weapons will always be available.

Decreased cost of ownership is possible from a number of aspects. There will be no cockpit or life support systems. This leads to a direct cost saving and, because of the decrease in weight, to a further indirect savings. Because the airframe will not have to be man-rated the amount of safety margin required will be decreased, which in turn will lower manufacturing and O&S costs as well as decrease test and evaluation costs. In addition if we think of the air vehicle as just another subsystem we could look at balancing the cost of maintenance vice that of replacement. This would mean building the air vehicle for finite use rather than as the longest lived subsystem, and then replacing it if it is cost effective to do so.

One example of how operation and support costs might be reduced is that of flying hours. One option would be to build the vehicle for a pre-selected number of flight hours. If we choose 1,000 flight hours as the total we can get significant cost savings. Let us assume 800 hours combat and 200 hours training. This 1,000 flight hours is roughly one-eighth the number of flight hours, takeoffs and landings as a typical F/A-18. We further assume savings accrue as a *pro rata* percentage of total program cost and use the life cycle costs (LCC) data generated by the Joint Advanced Strike Technology program.

From procurement we have a savings of 7/8 of the cost of initial spares, which is 2% of the LCC. This gives a 1.8% LCC savings. From operations and support (O&S) we have a savings of 7/8 of the cost of unit level consumption, maintenance, and support. This has been calculated to be 30% of the LCC, which leads to a savings of 26.2% of LCC. Note that this savings comes from the peacetime O&S costs, traditionally the most difficult funds to obtain. Taken together these give a life cycle cost savings of 28% just from reduced peacetime flight hours. Additional savings could also be available from reduced unit procurement costs and possibly from reduced manning levels and base support for training. The unit procurement costs need to include the cost of ground stations supporting the JSAAWS; one unresolved issue is the number of JSAAWS that could be supported by each ground station.

Other potential sources of overall system cost savings include: a JSAAWS, because of its inherent survivability, would also not require a large strike support package and the number of support aircraft could be decreased; most training could be performed by simulation decreasing training costs beyond just those from decreased flight hours - for example we would no longer need to build flight trainers; increased survivability could also allow the use of shorter range, less expensive, expendable ordnance such as guns, rockets, and dumb bombs. Higher lethality, because of increased weapons delivery accuracy, also means that less ordnance of any type would need to be used on any target.

Other areas of potential cost savings that will need to be investigated include a decreased logistics footprint and a decreased support infrastructure, including the possibility of decreased manning levels.

A JSAAWS will allow a Naval Expeditionary Force (NEF) to have a much more aggressive presence when it is first on the scene, or at any time. The NEF will have limited assets, typically one carrier battle group, yet in the early stages of a crisis or a conflict that erupts suddenly it might have to carry out the full range of missions. Also because by definition we are trying to bring the fight to the enemy, our adversaries will either be within their own borders or just across from them. Thus, in addition to interior lines of supply, they will have access to their entire stockpile of assets, all of which we may not know about, either their location or their capability. Also, at least at first, we are likely to be in a reactive mode because an adversary's intentions might not be fully known.

Because there is no danger of casualties a JSAAWS will allow us to fly against an unknown adversary as one way to assess his strength and intentions. Using it aggressively will also allow us to impact the outcome early on in either a Forward Presence/Crisis Response situation or in the first days of a campaign.

One caveat to this is that in the early days of JSAAWS incorporation into the Force Structure we are likely to be as cautious of their use in high risk situations as we are now with manned aircraft or current UAVs. As an important asset, the loss of even one would be a serious consideration. But if we can change the mindset then we can move to a more liberal use of these systems.

4 CHANGE THE MINDSET

In our approach we will not just "put weapons on UAV" or "take the pilot out of cockpit" either physically or mentally, or produce "more capable one-time use weapons." Rather our proposal for JSAAWS is for a total weapon system designed for the tasks at hand.

One thing that needs to be done to maximize the benefit of a JSAAWS is to break out of our old ways of thinking about aircraft and weapons from both an operational perspective and in the engineering design.

Operationally we need to think about using a JSAAWS as if it were a weapon and not an aircraft. This new approach means that operationally mission lines can blur when we consider how to use a JSAAWS. New missions can also be considered, and old missions that were abandoned for various reasons can be reconsidered. In this context JSAAWS changes the calculus of attrition, survivability becomes strictly an economic and warfighting effectiveness issue, not an issue of casualties. This, coupled with the postulated increased capabilities of a JSAAWS, allows us to look at new tactics for its employment. It also allows us to look again at older tactics that have lost favor because of survivability concerns.

On the engineering design side we need to stop thinking of JSAAWS as aircraft or a UAV and start thinking in terms of a weapon system. To build such a system might require us to combine the expertise of those who can cost effectively build re-usable vehicular platforms with those who can design and build weapons that work the first time, even after many years of storage.

We need to get around our notion that aircraft break if they are not used and to think "All Up Round" for a JSAAWS. Since most will not be in peacetime use, but need to work the first time out of the box during hostilities, we need to be concerned from the first with designing in total system reliability, and to back that we need built in tests (BITs) that check a greater percentage of probable potential failure modes, compared to manned aircraft.

Another example - aircraft have tops and bottoms and sides, but should a JSAAWS? And if it does have a top, bottom and sides, should the inlet go on top to mitigate signature issues, and should the ground looking sensors go on the bottom? While just the opposite of manned aircraft, these may be the best JSAAWS system solution.

Another option is to missionize JSAAWS so that it carries only what it needs for a specific mission. Make all subsystems "Plug and Play", and make the Air Vehicle just another subsystem. Look at balancing the cost of maintenance vice that of replacement. Think about building the air vehicle for finite use rather than as the longest lived subsystem, and replace it when it is cost effective to do so. These and several other considerations are shown in Table I.

Table I. Aircraft - JSAAWS - Weapons Comparisons

Aircraft	JSAAWS	Weapons
High value asset	Capable, reusable ultimately expendable	Expendable
Pilot in vehicle Non-autonomous	Operator not in vehicle Semi-Autonomous	No operator Autonomous in free flight
Requires constant maintenance	All-up-Round, but Maintain during combat	All-up-Round
Build to maintain Multiple flights (~8,000 hr)	Build to replace Multiple flights (~1,000 hr)	Build to use once Free flight (~2 hr) Many captive carries
Air Vehicle primary subsystem - 70% unit cost	No primary subsystem - cost and capability uniformly distributed	Guidance & Control primary subsystem - 60% unit cost
Training/proficiency flights >95%	Combat flights ~80%	Combat flights ~ 95%
Fly to retain pilot proficiency	Fly to retain maintenance proficiency & check system readiness	Fly to check system readiness
Unit cost $30M-$80M	Unit cost (goal) <$10M	Unit cost <$1M
O&S unit cost $30M-$80M	O&S unit cost (goal) <$5M	O&S unit cost 20% unit cost

What we are trying to capture here is the idea that traditional military aircraft are built to do a lot more than deliver ordnance. In fact their primary function is to bring themselves and the pilot (both valuable, scarce assets, back to the ship. Typical survival probabilities for manned aircraft in combat are greater than 0.998 per sortie, while typical probabilities of killing a target for the same aircraft are less than 0.5 per sortie. Compare this to a JSAAWS that has as its primary function delivering weapons on targets. Thus we need to be weapon delivery centric in our designs rather than pilot centric.

This means that certain subsystems can have different requirements depending on whether they are being used in the air vehicle mode or the weapon system mode. In some cases not only are the requirements different, but entirely different data are needed by the two systems, air vehicle and weapon system. In general for a JSAAWS weapon system, requirements will be more stringent then air vehicle requirements. Take as one example the navigation system. In an aircraft (air vehicle) the purpose of this system is largely to get from point to point and the horizontal position only needs to be known to within hundreds of meters, while for a weapon delivery system this needs to be known to within meters. For vertical position aircraft use barometric pressure, which is good to within tens of meters, while the weapon system needs this to within meters. Aircraft normally need to know ground speed to within 2-4 km/hr, while a weapon system needs this information to within cm/sec.

Both the uninhabited aircraft and the armed UAV have their proponents. Our view is that if one or the other of those approaches is the only one taken then we will be, in effect, limiting our options before we even start to look at the issues. Each of those approaches has an existing community and an existing mindset, not to mention existing hardware, that it will bring to the table. If the implementation is simply bringing together existing components, i. e., existing weapons and platforms, then it might be available quickly, and would be valuable for initial looks at the operational issues involved in fielding such a system, but such an implementation will not be an optimized system and will not take full advantage of the concept either in performance or affordability. To maximize the benefit in terms of cost effectiveness of JSAAWS we need to break out of our old ways of thinking about aircraft and weapons from both an operational perspective and in the engineering design.

5 MISSIONS

We have looked at several missions for a JSAAWS, some of which are more compatible with a JSAAWS then others. These are: SEAD, Battlefield Support / Simplification, Armed Recce, ASuW in the Littoral, supporting Operational Maneuver...from the Sea, Counter Cruise Missiles, Offensive Counter Air, and Defensive Counter Air. Our initial thoughts for these missions are presented below.

SEAD. This is the initial mission of choice for those elements of the operational community with whom we have discussed this concept. A survivable JSAAWS, as postulated above, increases the options to do lethal, non-lethal, or no SEAD. The threat/target can be attacked from multiple directions. Non-lethal options are similar (but not identical) to those for manned aircraft; cheap disposable jammers, chaff delivered in more flexible corridors or directly over a radar, self jamming where decreased range allows for smaller power/aperture. Lethal options include using cheaper, general purpose weapons. Because of the potential for nap-of-the-earth flight, decreased size and observability and increased maneuverability, JSAAWS will also be more survivable against pop-up SAMs. This allows JSAAWS the flexibility to ignore air defenses, if the pre-briefed mission is time critical or to attack them if not.

Several employment tactics have been considered. Terminal evasion and very low level (~50 ft.) flight are two that look attractive. The continuous threat of attack by a nap-of-the-earth JSAAWS will drive threat radar to be on more making them vulnerable to HARM attack. The net result is that SEAD changes from a requirement to an option.

Battlefield Support/Simplification. This is a combination and evolution of Close Air Support (CAS), Battlefield Air Interdiction (BAI), and Air Interdiction (AI). CAS is a time critical mission, needed to help ground forces. Because we generally don't know what the ground-based threat will be it is dangerous; however survivability must not be an issue in determining if it is carried out or not. Being unmanned and highly survivable JSAAWS can carry out this mission under all circumstances and in the shortest possible time.

Concealment, camouflage, and deception (CCD) capabilities of military ground vehicles are rapidly increasing, while signature control is increasing. All of this makes it harder to find and identify mobile targets when they are stationary. There are a lot of targets in total and achieving multiple kills per sortie, rather than the current multiple sorties per kill, would be a real plus.

One option with a JSAAWS would be to only attack these targets, armor, APCs, artillery, etc., just before they get close enough to the forward line of troops (FLOT) to impact troops on the ground. Getting them while they are moving will to some extent mitigate the CCD issue. This also does away with the longer, less productive, BAI and AI missions against these type of targets and so increases efficiency. It also decreases collateral damage considerations. The targets will be far enough away from our troops so friendly fire is not a worry, but close enough to the FLOT that there will be minimal enemy collateral damage considerations because everything will soon be in the field of fire from ground forces. We could have a rolling kill line just far enough in front of the ground forces so that we minimize time to kill while not putting ground forces in jeopardy.

This has psychological consequences. If an enemy knows he can/might be killed anywhere he has no reason not to get to the FLOT to fight back. If however he knows that the likelihood of being killed from the air increases by a lot within, ten kilometers of the FLOT, he might be less inclined to hurry to get there.

Armed Recce and ASuW in the Littoral. These two missions have many common characteristics. The environment and ROEs highly asymmetric. They are carried-out in congested environments where targets will be among many non-targets and collateral damage is a major issue. Hence there are many more restrictions on us than on an adversary. Pop-up threats will be present and we will be looking to engage relocatable and moving targets. These things require either self targeting or continuous targeting from off-board assets. A survivable JSAAWS allows a longer time within which to make shoot/no-shoot decisions. If identification is a problem JSAAWS can get closer to a potential target thus increasing the probability of proper identification and decreasing the probability of killing the wrong thing. If a no-shoot decision is made and JSAAWS is lost no pilots are lost and the consequences are not as great.

Operational Maneuver ...from the Sea. The US Marines are developing several tactics in this area involving distributed combat cells. One example involves landing several small forces, separated in distance, who can mass fire on a given target from diverse locations rather than massing manpower and allowing easier detection and coordinated response by our enemies.

These forces will need to be able to call fire when and where it is needed. One possible solution is for several JSAAWS to loiter close at hand over enemy soil, to act as organic assets for each fire team. This would allow for precise time-on-target and rapid response without exposing pilots to extended missions in high-threat environments.

Counter Cruise Missiles. To defend against these missiles in flight is a difficult mission. If the attack is by missiles launched from dispersed sites and targeted at either dispersed sites or a single site there are a number of functions that must be accomplished. The first function is to find them. This could be done by airborne or spaceborne assets. The difficulty will arise from the degree of stealth in the cruise missiles. The second function will be to intercept the cruise missiles before they reach the target. If the missiles are carrying chemical, biological or nuclear weapons then the issue becomes one of intercepting them before they cross the FLOT. Finally the missiles must be destroyed. One solution to the intercept problem is a very fast counter-cruise-missile missile, keyed by the observation platform and launched from a surface or airborne platform, and having sufficient guidance and fuzing capability to get to and destroy the cruise missile. The issue here is cost and capability. Another solution is wide area coverage provided by a few highly capable forward-deployed JSAAWS, which can both target and shoot at the missiles. This mission will require a highly capable sensor suite to provide the wide area coverage, even if cued from other assets, and either a high speed JSAAWS or a high speed, high capability weapon. A high speed JSAAWS would provide the challenge of mixing loiter and speed in a single airframe. A third solution is to provide high density coverage over a defensive belt using numerous, mediocre, but armed, JSAAWS. The belt must be wide enough to allow for second chance detections and second shots. The key will be sustainability of large numbers of loitering airborne defenders. These JSAAWS would need loiter capability and sensors that can detect ground-hugging, low observable threats. The key will be to keep the price down, while maintaining sufficient capability.

If the attack is by a large number of cruise missiles, more ordnance is necessary to destroy them. This presents payload issues for the JSAAWS, be they few and capable or many and mediocre. No matter how many JSAAWS there are there will be more cruise missiles and some JSAAWS will be called upon to deliver multiple kills. If this is done with close-in weapons such as guns and rockets then the JSAAWS must make each kill quickly and then move on the catch the next cruise missile. This will require a JSAAWS with high speed. If longer range weapons are used the JSAAWS will need to carry enough of them to kill a sufficient number of the cruise missiles.

Offensive Counter Air. This is a time critical mission. Attack of highly defended airfields with readily identifiable targets, such as runways and revetted aircraft, is well suited to a JSAAWS. Aircraft are easier to find and kill on the ground. They don't maneuver or shoot back with highly capable air-to-air missiles, although airfield air defenses do shoot back, and they are cheaper to kill on the ground using things like guns, rockets, dumb bombs, or even JDAMs, vice AMRAAM or AIM-9 in the air. The use of guns and rockets would also increase the number of kills per sortie because of the ability of the JSAAWS to carry more bullets or rockets than bombs.

Defensive Counter Air. A highly maneuverable JSAAWS would overcome the exchange ratio problem. Such a system could either survive most missile attacks or defeat threat aircraft in the merge/post-merge battlespace by out-maneuvering them and destroying them before they launch their close-in missiles. Also the psychological consequences on an enemy if he knew he was facing an uninhabited system rather than another pilot could be extremely demoralizing.

Some arguments on exchange ratio make the case that we won't have to worry about fighting superior aircraft and weapons because no adversary can afford many of them. They are bought not to fight NATO but to intimidate, and be used against, regional rivals and they won't be risked against us because we have superior pilots and vastly superior numbers. However, even if we do end up fighting superior aircraft and weapons we will eventually defeat them, and if it takes the loss of some of our aircraft that will not impact the campaign because of our overwhelming number advantage.

This argument breaks down if zero casualties becomes an explicit, or implicit, requirement as it might in less than MRC level conflicts. Witness the Scott O'Grady affair in Bosnia where we risked the lives of many more personnel and the loss of much more equipment to try to prevent his capture. It also breaks down in scenarios where the Navy is the first or the only service on the scene. Under those circumstances we have very few aircraft on scene and can't afford to lose any. It also breaks down in enforcing no-fly zones when we might see exclusively few on few engagements. These engagements will all be at the adversary's initiation and could put us either at parity or at a numerical disadvantage at the time of the fight. This coupled with superior weapons in an adversary's hands could make enforcing a no-fly zone either impossible or extremely expensive as we increase the number of platforms on patrol.

JSAAWS also helps overcome some IFFN issues. Currently survival in air-to-air engagements is largely a matter of killing your opponent before he shoots at you. This means getting the first shot off at fairly long ranges, which can be in conflict with ROEs that say we need positive, visual, identification. With a JSAAWS that is survivable by means other than killing the opponent, for example superior maneuverability, we have the option of switching to an ROE that is - kill only when positive identification has been made - with very little danger of losing a JSAAWS.

One option would be to only fire if fired upon or to use a datalink to have a remotely located operator make the firing decision. Since there is no danger of losing a pilot, and the JSAAWS would be highly survivable, it could get a lot closer to the incoming aircraft before it had to make a decision on what actions to take.

While survivability might not be as much of a concern for the F/A-18 E/F and the F-22, both of which are postulated to be much more survivable than the air superiority fighters of the past, it will continue to be an issue for the older generation of aircraft that would still be part of the force mix if not replaced by a JSAAWS. Another potential advantage of using JSAAWS is that if the only manned fighters in the air are the adversary's, we could exercise the option of risking a beyond visual range shot with only reasonable indication (>95%) that the aircraft is an enemy; whereas if we had manned aircraft in the area, the requirement would be >99.999% positive visual identification.

6 FUNCTIONAL CONCEPTS

Three concepts have been defined that cover all of the missions for a Naval Expeditionary Force. They are also from diverse parts of the potential design space.

The high-end concept is the Highly Maneuverable Lethal Vehicle presented in detail in paper 4 of this Conference.

It relies on capabilities superior to the threat in almost all areas to achieve lethality and survivability. Cost savings are obtained through decreased O&S and improved effectiveness.

This would be a multi-role system for most air-to-air and air-to-surface missions. It is very capable, but could costs as much as, or more than, a manned aircraft. This system has an extensive sensor suite for both targeting and survivability. Data link requirements are limited because the system is highly intelligent, and highly autonomous. It is highly maneuverable and requires some countermeasures. It uses short range, light, inexpensive weapons. Our view is that extensive technology development is needed in some critical areas before system-level demonstrations are viable.

The air arsenal ship is a concept that has been put forward by the US Air Force. It would have limited air-to-air and air-to-surface roles. Potential missions include Strategic Strike, OCA, Littoral ASuW, Armed Recce, Counter TBM and Cruise missiles. It requires a long range sensor suite for targeting and would have extensive datalink requirements because it would serve in a surveillance and reconnaissance role as well as a lethal role. It would be moderately intelligent and moderately autonomous. It relies on very high altitude and very low observability for survivability. It would employ current and advanced long range weapons. To take full advantage of its very long time on station it will need a large loadout of weapons. Cost savings are obtained via decreased O&S. Extensive technology maturation is needed in several areas before system-level integration demonstrations would be feasible.

The low-end concept would have capability in a limited, but operationally significant, set of air-to-surface missions, CAS, BAI, AI, SEAD, Indirect Fires. However included in this mission set are a significant number of the total targets. It achieves survivability by aggressive nap-of-the-earth flight, requiring a terrain and obstacle avoidance system. It could have a missionized sensor suite. Targeting will all be at short range requiring either a minimal on-board sensor suite or potentially the use of off-board targeting and GPS only on-board. It would have moderate datalink requirements because most communication would either be short range or via relay systems, and the data presented will be limited imagery of the proposed targets. Because of the limited mission set the system will only be moderately intelligent and have limited autonomy. It will utilize existing inexpensive weapons, such as guns, rockets, and dumb bombs in a direct attack mode wherever possible. STOL capability is inherent in the concept which would make for easier carrier integration or use on small deck ships Integration demonstrations, not technology development, is needed to help mature this concept. Cost savings are obtained via a lower unit cost, decreased

O&S, and use of existing, inexpensive ordnance.
One other attractive implementation could be a V(S)TOL version. This would allow use by the Marines at minimal on shore facilities. It would also make carrier integration easier by using less deck space, for example helo pads. It would also allow the use of any air capable ship as a launch platform. The low end concept, whatever its implementation, is the preferred concept for initial introduction of a JSAAWS since it requires the least RDT&E, is the lowest cost, and still takes on some of the most important air-to-surface missions.

7 CONCLUSIONS

JSAAWS is a new aviation concept. As such it is a highly complex system that is part of a much larger, and hence even more complex system of systems. There are similarities to aircraft, UAVs, and weapons, but there are also fundamental differences that must be understood before we will have an optimized system. Such a system would provide an opportunity to "break the mold" of expensive upgrades to expensive-to-maintain aircraft nearing the end of their useful life, as well as providing a potential solution to the fundamental problem of cost of ownership. JSAAWS cannot be considered separate from investment in the rest of force structure and before we make any major investments we need to thoroughly understand their potential contribution to Naval Aviation. If JSAAWS are to be implemented we will need a deliberate and planned evolution to maximize leverage of legacy force. In order to minimize cost and maximize benefit we need to begin understanding and planning now.