

# Conceptual Design of a Ducted Fan-Based Vertical Takeoff and Landing Tactical Unmanned Aerial Vehicle

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## Abstract

V-STAR™ (Vertical Takeoff and Landing Swift Tactical Aerial Resource) is a tactical unmanned aerial vehicle (UAV) with a unique integration of historical aerospace design concepts. Using a single ducted fan for vertical takeoff and landing operations, V-STAR™ offers payload flexibility throughout its range of missions. This range of flexibility comes through the placement of cargo at the vehicle's center of gravity, which is in-line with ducted fan used for vertical takeoff and landing (VTOL) operations. In addition to the unique placement of the payload, the use of two turbine engines, placed for balance and functional integration, allows V-STAR™ to operate more efficiently during conventional forward flight. This approach increases range and endurance capabilities while providing greater reliability and safety for the mission. The configuration of the wing provides distinct advantages from both a structural as well as aerodynamic perspective. These aerodynamic benefits allow for mission adaptability through the use of wing-tip extensions and in-flight wing planform modifications. Finally, V-STAR™ incorporates the MicroFire™ engine recuperator to provide heightened fuel efficiencies for its turboshaft engines. Through the integration of these design concepts, the V-STAR™ architecture allows for high flexibility and excellent competition among the current high drag, rotor-based unmanned designs.

## Nomenclature

- $C_L$  - Wing Lift Coefficient
- C - Cost (\$)
- E - Empty weight (lb)
- F - Fuel weight (lb)
- N - Noise (db)
- FM - Figure of merit
- O - Observability
- P - Payload weight (lb)
- R - Range (n.mi.)
- RES - Reserve fuel weight (lb)
- TOGW - Takeoff gross weight (lb)
- TRAP - Trapped fuel weight (lb)
- V - Velocity (kts.)

## Introduction

Vertical takeoff and landing vehicles have garnered interest from the public ever since the first helicopter took flight. By offering the ability to take off and land in remote areas and on various terrains, VTOL vehicles are continually designed to leverage these capabilities while maintaining the speed and efficiencies of conventional aircraft. However, despite the work that has been done on VTOL aircraft over the years, the VTOL UAV sector remains rather young; few operational offerings exist and of those, the majority are low disk loading, rotor-based designs.

Over the years, aircraft designers have taken a myriad of approaches in order to achieve the forward flight efficiencies experienced by conventional tube-and-wing aircraft. Low disk loading, rotor-based designs often have the most difficult time overcoming this hurdle, as the rotor isn't used during forward flight yet becomes difficult to "hide" when not in use. Design strategies for slowing the rotor help reduce the overall drag but in the end will be at a considerable disadvantage when compared to a fixed-wing design.

In the figure below (Figure 1), the Fairey *Rotodyne* is shown to illustrate a historical example of an aircraft designer's attempt to merge VTOL capabilities with forward flight efficiencies using a conventional wing and a separate forward propulsion system



Figure 1 – The Fairey *Rotodyne*<sup>2</sup>

Throughout the design of the V-STAR™, these challenges were considered and addressed in a unique manner, providing a system that incorporates VTOL capabilities with efficient forward flight operations.

### Preliminary Design

In order to determine the initial sizing of the V-STAR™ vehicle, calculating a preliminary takeoff gross weight and empty weight were required. As is often done in the first stages of a new aircraft design, historical aircraft were used to generate the initial weight trend, utilizing aircraft that perform a mission in a manner similar to the aircraft being designed. For the V-STAR™'s initial sizing, aircraft beyond historical VTOL UAVs were required in order to provide enough data points to generate a sufficient trend, thus Analytic Services' (ANSER) V/STOL wheel was used to help define the historical weight trend.

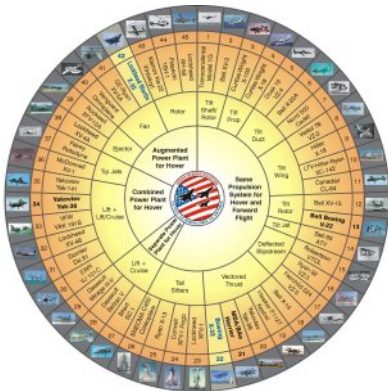


Figure 2 – ANSER's V/STOL Wheel<sup>1</sup>

Using select vehicle's from the ANSER wheel, a weight trend was generated and a trend line was fit to the data (Figure 3), creating the weight equation (Equation 1) that defines the empty weight to the takeoff gross weight for the type of aircraft chosen in the sample. While this grouping of aircraft not only includes contemporary VTOL UAVs such as the Bell *Eagle Eye*, it also incorporates aircraft designed in the mid-twentieth century that utilize a wide variety of VTOL approaches.

$$W_{EMPTY} = 0.4988W_{TOGW}^{1.0267} \quad (1)$$

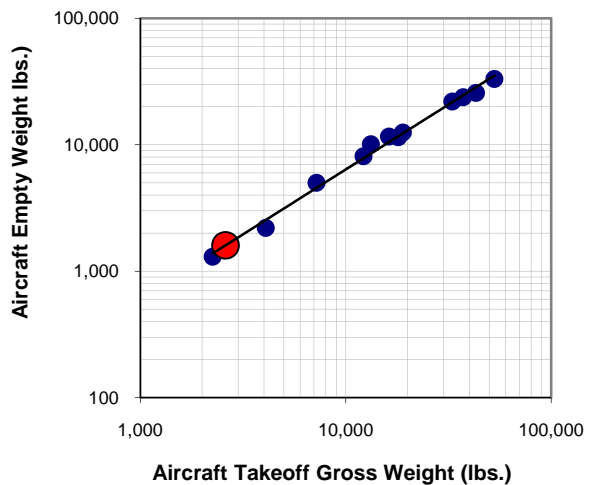


Figure 3 – VTOL Weight Trend for Weight Sizing

Of note in Figure 3 is the trend generated by aircraft using different propulsion approaches. As mentioned earlier, both VTOL UAVs and manned VTOL aircraft were used in the study; in addition, both propeller-based aircraft along with jet-based aircraft were included in the study. Despite this seemingly large difference between propulsion options, the weight trend displays minimal error in relation to the generated trend line.

The primary design criterion for the V-STAR™ was to fill the need for an autonomous resupply aircraft. Such a mission requires dense payloads to be delivered to troops in remote locations, often very quickly, while maintaining as small an audible trace (noise signature) as possible. These design factors drove V-STAR™'s sizing in various ways, the first of which was through the selection of payload weights.

Utilizing the above equation along with the initial mission profile, aircraft assumptions (Table 1), and the weight fraction method<sup>3</sup>, the V-STAR™'s initial takeoff gross weight and empty weight were estimated to be

2,360 lb and 1600 lb respectively (Table 2). As seen represented by the larger data marker above in Figure 3, the initial takeoff gross weight estimated by the trend line and weight fraction method falls towards the bottom of the data set but remains in-line with the data in the graph.

**Table 1 – Initial Mission Profile and Assumptions**

Mission Requirements		
Item	Value	Units
Payload	400	lb
Range	400	nmi
Cruise Speed	300	kts
Cruise Altitude	15,000	ft
Mission Assumptions		
Loiter Speed	180	kts
Max $C_L$	1.6	-
Wing Loading	85	lb/ft <sup>2</sup>
No. of Engines	2	-
Cruise Throttle	85%	-
Cruise TSFC	0.55	lb/lb-hr
Cruise $C_L$	0.30	-
Stall Speed	125	kts

**Table 2 – Initial Weight Estimations for V-STAR™**

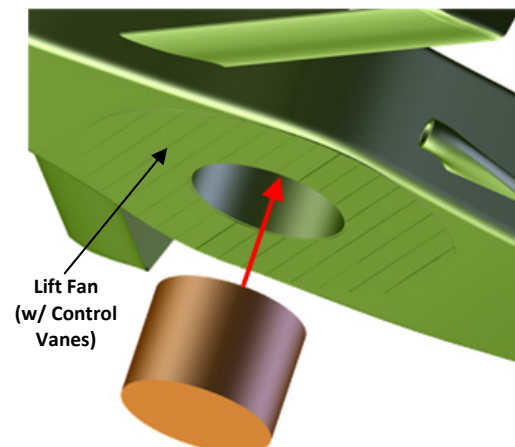
Category	Weight (lb)
$W_{TOGW}$	2,360
$W_{RES}$	130
$W_{TRAP}$	26
$W_{FUEL}$	602
$W_{EMPTY}$	1,600
$W_{PAYLOAD}$	398
$W_E/W_{TOGW}$	61.6%
$W_F/W_{TOGW}$	23.2%
$W_P/W_{TOGW}$	15.3%

As noted in Table 1 above, a payload weight of 400 lb was selected in order to size the vehicle. While the takeoff gross weight of 2,360 lb may appear to yield a small vehicle to carry 400 lb, the main elements of the resupply mission are to deliver dense payloads, e.g. water, food, batteries, and ammunition. Recognizing the nature of the payloads around which the vehicle

was designed lead to the first major design innovation on the V-STAR™.

### Initial Configuration and Vehicle Layout

Realizing that VTOL aircraft are very sensitive to the aircraft's center of gravity (c.g.), V-STAR™ was designed around the payload bay, providing flexibility in the weights of payloads that V-STAR™ can carry. In order to accomplish this design feature, V-STAR™ is designed with a counter-rotating ducted fan used for vertical takeoff and landing. This central fan, featuring an empty hub in the center, allows payload to be placed at the center of the fan and thus minimizes the concern surrounding payload weight limits. Figure 4 below shows the payload integration at the center of the vehicle's lift fan.



**Figure 4 – V-STAR™ Payload Integration**

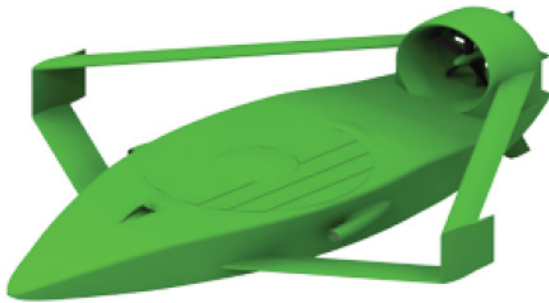
By placing the payload at the center of the vehicle's vertical lift vector, the importance placed on the size and the weight of the payload are minimized, leaving only the engines, fuel, permanent systems, and the vehicle's structure to be balanced around the center of lift. In addition to the flexibility in shape and weight, the bottom-loading aspect and semi-spherical field of view of the payload integration allows for a myriad of payload types to be integrated into V-STAR™, ranging from internal resupply payloads, for which it was designed, to external surveillance and/or communication equipment and even weaponry.

As seen in the figure above, the central fan was also designed with a series of control vanes on both the top and bottom of the aircraft. After full transition to forward flight has occurred, the vanes of the vehicle are designed to close, providing lower drag for the

vehicle than an open duct. In addition, the vehicle's bottom vanes aid the vehicle in stability and control during hover operations by constantly attenuating themselves and controlling the duct's exit flow.

The presence of a duct in the middle of the aircraft presented an early design challenge with respect to the integration of the aircraft's wing. In order to properly position a conventional wing's lifting point with the aircraft's c.g., the wing's torque box would be in the middle of the duct. In the early stages of the vehicle's layout, this was ruled out, as the structure could cause disruption in the duct flow and potentially place stress on the duct that would adversely affect its geometric efficiencies.

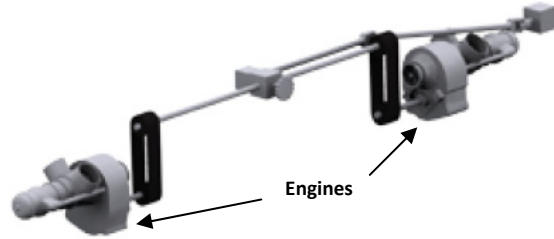
In order to circumvent these problems, V-STAR™ is designed with a diamond box wing (Figure 5), a modification of a joined-wing approach first proposed by Julian Wolkovich<sup>4</sup>. While allowing the wing's torque boxes to be placed fore and aft of the center duct, the diamond box wing approach provides two additional benefits: exact c.g. placement and exhaust suction minimization.



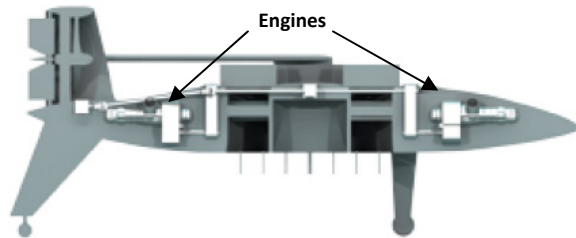
**Figure 5 – V-STAR™'s Diamond Box Wing**

In the preliminary design phase, the ability to change the fuselage station of the wing joints, essentially changing the sweep on both the front and rear wings, allows for the wing system's center of lift to be placed where desired. Additionally, the lack of a horizontal surface directly next to the exhaust of the central duct helps reduce the downward suction that often occurs with VTOL vehicles and the low pressure region created by the exiting flow.

For forward propulsion, V-STAR™ is designed with a rear-mounted ducted fan. In order to power both the rear-mounted ducted fan and the central lift fan, V-STAR™ incorporates two Rolls-Royce Model 250 turboshaft engines. Figure 6 shows the engine-linkage system while Figure 7 depicts the engine placement inside of V-STAR™'s fuselage.



**Figure 6 – V-STAR™ Engine Linkage System**



**Figure 7 – V-STAR™ Engine Integration**

In order to power the central lift fan, both engines are coupled together at the central transmission hub, using gears to reduce the speed and combine the power of both engines. This approach, shown in Figure 6, utilizes belt drives and linkages in order to allow the rear engine to power the rear-mounted ducted fan. With the two engines used to power the vehicle for takeoff and landing and only one engine used for forward propulsion, V-STAR™ incorporates a redundant engine system whereby either engine can power the rear-mounted ducted fan or provide increased power to the rear fan for a "dash speed" exceeding 400 knots. Due to V-STAR™'s design for operating in remote, front line areas, engine redundancy allows the vehicle to sustain damage while continuing its conventional flight operations, even providing reduced descent rates through the partial-powering of the central lift fan.

### **Mission Adaptive Planform**

Due to the uniqueness of the diamond box wing arrangement, V-STAR™'s configuration can be manipulated to increase the overall wing planform area without affecting the overall stability and balance of the aircraft. Various design approaches that leverage this feature were studied early on in V-STAR™'s configuration and include both removable wingtip

extensions (increase the area about the aircraft's center of lift) as well as in-flight deployable extensions.

With the ability to add bolt-on extensions onto the wingtips of diamond box wing (Figure 8), V-STAR™ has the potential to increase the aircraft's overall lift-to-drag ratio, thereby increasing its range and endurance during operations.



**Figure 8 – Wingtip Extensions Attached to V-STAR™**

Because the extensions' center of lift are placed at the same fuselage station as the main wing's center of lift, the overall effect on the aircraft's static stability is minimal, allowing any number of extension configurations, whose size is dictated only by the structural capabilities of the diamond box wing, to be placed onto the aircraft.

Beyond a bolt-on extension, the features of the diamond box wing allow for in-flight modifications to the wing, similar to the principles achieved from state-of-the-art wing morphing designs. By integrating pivoting extensions into the top and bottom of the wing's endplates (Figure 9), V-STAR™ is designed with the capability to increase its overall planform area during flight.

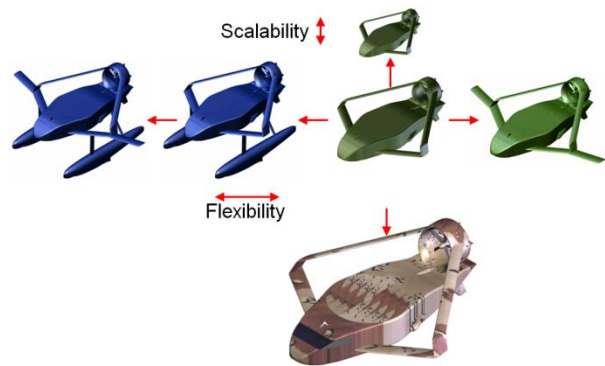


**Figure 9 – V-STAR™ Wingtip with MAP**

This design approach, termed Mission Adaptive Planform (MAP), could allow V-STAR™ flight segments

of heightened endurance times (extension deployed), followed by a high cruise speed segment (extension retracted). This integration of an adapting planform can provide a flight vehicle with a strategic advantage against other designs.

In addition to allowing the wing planform area of V-STAR™ to be scaled, it is perceived that the coupling of the diamond box wing and aircraft c.g. location allow for the vehicle as a whole to be scaled up and down with minimal effects on the number of design iterations required. Figure 10 depicts the 2-D configuration scalability that the V-STAR™ could undergo, depending on mission requirements.

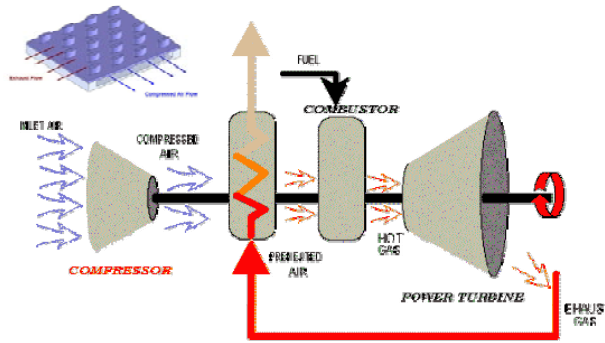


**Figure 10 – Flexibility and Scalability with V-STAR™**

This above graphic demonstrates the flexibility that the V-STAR™ platform provided during the conceptual design phase of the vehicle. Designing to a specific mission was achieved, but further exploration into the synergistic design features within the V-STAR™ configuration provide these capabilities.

### **MicroFire™ Recuperator Integration**

The idea of gas turbine recuperators is not new and has been a viable fuel saving concept since the invention of the gas turbine; the technical difficulty is in the specific engine integration, taking care to keep the overall system weight low so as not to negate the fuel savings achieved. Figure 11 outlines the basic premise behind the recuperator as is currently integrated into the two Model 250 turboshaft engines on the V-STAR™.



**Figure 11 – The Workings of a Recuperator**

As noted in the figure above, a recuperator is a special purpose counter-flow heat exchanger used to recover waste heat from exhaust gases. In many types of processes, combustion is used to generate heat, but the recuperator serves to reclaim this heat in order to recycle it. In a gas turbine engine, the incoming air is compressed, mixed with fuel, and then burned to drive a turbine. The recuperator transfers some of the waste heat in the exhaust to the cooler compressed air, thus preheating it before entering the fuel burner stage. Since the gases have been pre-heated, less fuel is needed to heat the gases to the turbine inlet temperature. By recovering some of the energy usually lost as waste heat, the recuperator can make a gas turbine significantly more fuel efficient.

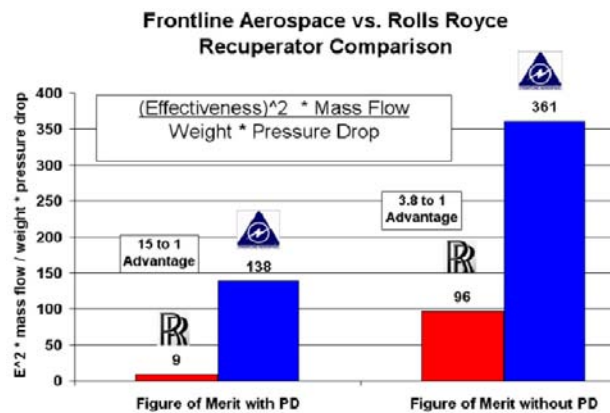
Historically, in aerospace and aircraft applications of Carnot cycle recuperators, the fundamental technical challenges preventing the recuperator's implementation have been weight, volume and sufficient performance to create a strong value proposition for potential users. Frontline Aerospace's patent-pending microchannel heat exchanger technology creates an opportunity for V-STAR™ using the Model 250 engine. The key performance specifications and features for V-STAR™'s MicroFire™ include:

- Exhaust Drop-in Retrofit on the Model 250
- Mass Flow Rate – 3.5 lb/s
- System Weight – <50 lb (40% Gas Savings)
- Small and Compact
- Exhaust Bypass
- Patent-Pending
- FAA Supplemental Type Certificate

Frontline is not the first company to specifically look at the Rolls-Royce Model 250 engine family and create a recuperator design. Rolls-Royce itself, under contract

to the U.S. Army Research and Development and Engineering Command in April of 2004 completed a detailed report<sup>5</sup> and built test articles to take advantage of recuperation. However, they failed to solve the compelling issues of weight, volume and performance that have historically hampered recuperators.

Below in Figure 12 is a comparison between Frontline's MicroFire™ product and the Rolls-Royce Recuperator effort, contrasting the key technical parameters of mass flow, weight, effectiveness (fuel savings) and pressure drop (power loss).



**Figure 12 – Competing Recuperator Comparison**

As shown in the figure, MicroFire™ delivers a 15 to 1 relative improvement over the Rolls-Royce effort of nearly five years ago. The impact of the MicroFire™ recuperator on V-STAR™ performance is significant as evidenced by the improved range-payload diagrams shown in the next section.

### Mission Performance Estimations

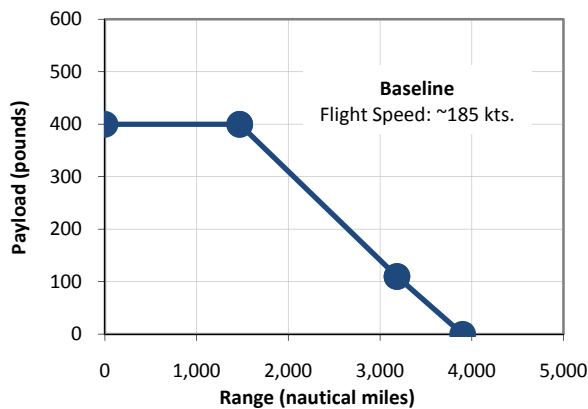
The preliminary design phase of the vehicle to determine the performance of V-STAR™, including the various design configurations and features, was done through a custom developed performance code. Custom software was required so as to incorporate the estimated aerodynamic effects of the diamond box wing as well as its unique drag estimations. For initial estimates of the overall aircraft's lift and drag, Digital DATCOM<sup>6</sup> was used to model the aircraft.

The Rolls-Royce Model 250 was modeled within the software and was thus used during each segment of the mission. This also provided the ability to modify the engine map and virtually add the estimated benefits of the recuperator. Re-running the mission performance with the modified engine allowed the

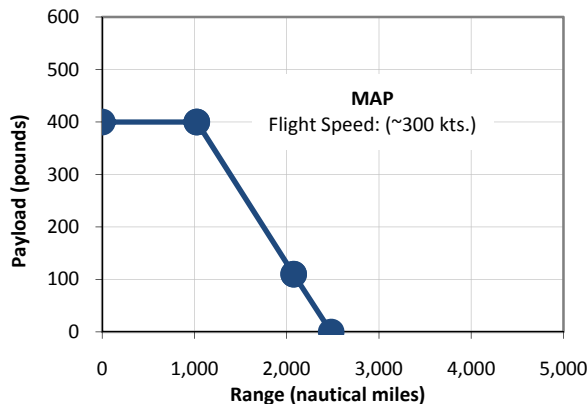
configurators to determine what effects the recuperator had on the V-STAR™'s performance.

Additionally, the initial estimates of the aircraft's overall lift and drag found in Digital DATCOM were supplemented by alternate DATCOM models, including both wingtip extension and MAP models to determine the preliminary effects of such additional aerodynamic surfaces. These configurations were distilled into classic drag polars which were incorporated into the mission performance code for fuel burn estimates.

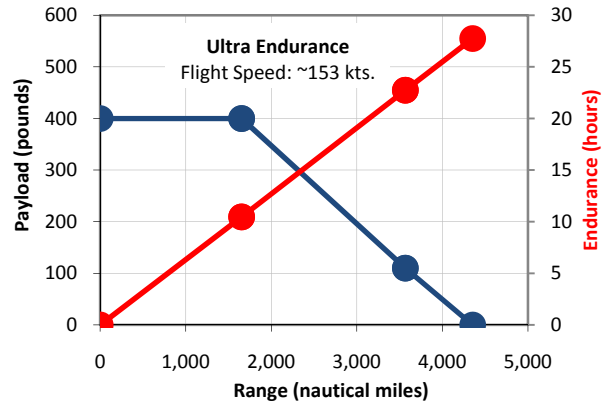
In order to compare the various design modifications such as the wingtip extensions and the MAP, payload-range diagrams were generated for each of the configurations and are shown below in Figures 13 through 15 and include the baseline configuration, MAP configuration, and endurance configuration (ten foot wing extensions) respectively. Each of the diagrams below contains performance numbers based on V-STAR™ with the recuperator and StandardAero's Model 250 engine modifications.



**Figure 13 – Payload-Range Diagram (Baseline)**



**Figure 14 – Payload-Range Diagram (MAP)**



**Figure 15 – Payload-Range Diagram (Wing Extension)**

As is evident by Figure 15, the extensions, coupled with the MicroFire™ recuperator and StandardAero's engine upgrades gives V-STAR™ a substantial increase in range and endurance. By adding extensions to increase the efficiency, the new wing configuration complements the recuperator to provide a new realm of flight capabilities and missions.

### Military Missions Comparison

Although V-STAR™ was designed originally for a logistics re-supply mission and the payload, range performance metrics were optimized for that purpose. It is worth considerable discussion around other key military missions and how other competitive tactical UAVs perform.

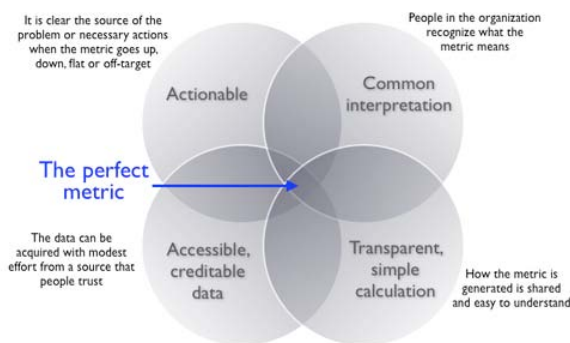
The core military missions of interest for this class of UAV are:

- Logistics—resupply of deployed troops
- Endurance—focused on long flight endurance and persistent Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR) applications
- UCAV—Unmanned Combat Aerial Vehicle
- Hunter Killer—mostly an ISR endurance mission with weapons
- Clandestine Resupply—quiet, fast, behind enemy lines resupply
- Casualty Evacuation—evacuation of the wounded from the battlefield

Each of these missions have different aircraft design requirements and ideal performance metrics. At the preliminary design phase it is hard to juggle, let alone

know all the key functional requirements and technical specifications. Nevertheless, most aircraft design teams will agree that speed, range, payload, noise, IR signature, radar signature, cost, life cycle cost, survivability and durability, all weather capability and landing zone flexibility are all valid metrics to outrank and compare to different UAV designs. Determining the perfect (just and fair) analytical metric to compare competing UAV designs is the final goal.

Figure 16 shows the *perfect metric* which requires four key elements: 1) a simple and transparent calculation (in the aircraft design case an equation that blends the key performance metrics i.e. speed, payload, cost), 2) a common interpretation of the metrics (designers all know what speed, range, payload are and can agree), 3) credible independent data published by the DOD via UAS roadmaps (for example), and 4) the military mission that will clearly benefit or lose from an increase or decrease in the *perfect metric* score.



**Figure 16 – Requirements for a Perfect Metric**

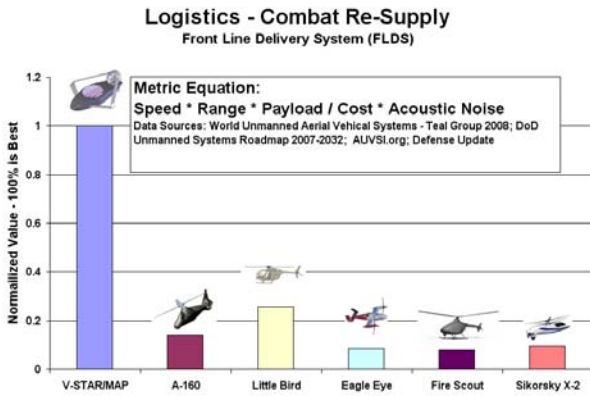
The question then turns to finding the reasonable (*perfect metric*) equations with which to judge each mission. Table 3 shows the equations derived by reasonable consensus amongst V-STAR™’s aircraft design and advisory team. With over one hundred years of experience designing aircraft, this team includes the following individuals: Darold Cummings (Boeing Technical Fellow, ran Boeing PhantomWorks exploratory concepts for five years), Rick Foch (Naval Research Labs, over 40 UAV designs to his credit), Dave Hall (former Lockheed and NASA Ames aircraft designer and lead configurator), and Empirical Systems Aerospace (conceptual aircraft design firm, detailed designs and tools completed for Boeing and NASA). Below are the outranking comparison equations (Equations 2 to 6) for each mission:

**Table 3 – Mission Comparison Equations**

Mission	Equation
Logistics	$FM = \frac{VPR}{CN}$ (2)
Endurance	$FM = \frac{PRE^2}{CO}$ (3)
Hunter/Killer	$FM = \frac{VPRE}{CO}$ (4)
Unmanned Combat Aerial Vehicle (UCAV)	$FM = \frac{V^2PR}{CO}$ (5)
Casualty Evacuation/ Clandestine Re-Supply	$FM = \frac{V^2PR}{CNO}$ (6)

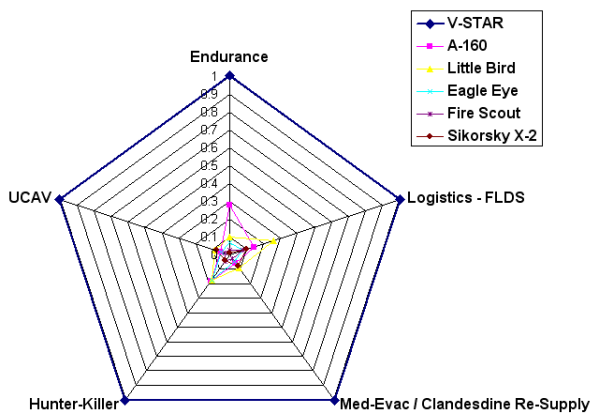
Some data are not known; thus the metrics of life-cycle-cost, IR and radar observability were not included. Secondary aspects were also omitted, such as survivability and landing zone flexibility due to insufficient and potentially inconsistent data. The data for competing VTOL UAV aircraft were compiled (Appendix A) and each equation was applied to the available data.

UAV costing can be difficult. What is integrated into a production per unit product cost is a complex blend of volume, development costs, payload options, and maintenance contracts. In order to be fair but potentially not that very accurate (+/-15%), regression equations created by Technomics, Inc, based on their work for the US Army, are used. They have evaluated dozens of UAV platforms, including all of the documents and cost breakdowns, and created credible metrics using TOGW, payload, endurance, production year, prototypes, etc. The cost data used in Appendix A are generated from these publicly available equations. In Figures 17 and 18, it can be seen that V-STAR™ outperforms competitors by a sufficient margin that slight amounts of error in the speed, weight, endurance time, etc. will not significantly change the overall outcomes. Figure 17 shows a normalized logistics mission comparison of the competitors and presents V-STAR™ as three to ten times better than the alternative designs.

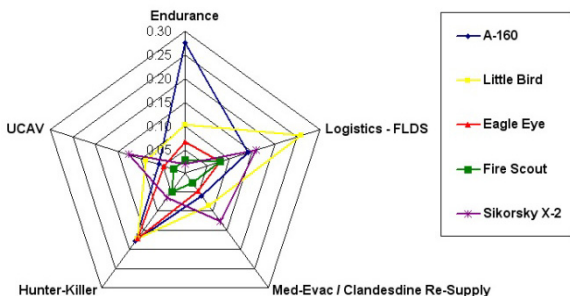


**Figure 17 – Combat Re-Supply Logistics Mission**

When each of the missions discussed are compared within a “radar diagram”, the results become even more dramatic (Figure 18 and 19).



**Figure 18 – Comparison of V-STAR™ with Its Competitors**



**Figure 19 – Comparison of V-STAR™ Competitors with Each Other**

These results stem from several key design elements of the V-STAR™ platform. The MicroFire™ recuperator improves fuel consumption and range, while the wing-morphing planform with its folding down and bolt-on wing tip extensions dramatically improve lift and drag ratios. The ducted fan VTOL design has relatively low noise and drag compared to those of helicopters while the diamond-box and high aspect wings allow for efficient high speed flight (nearly three times that of helicopters).

## Conclusion

Through a conventional conceptual design approach, a unique blend of historical and state-of-the-concepts has produced the V-STAR™ platform. Through the implementation of recuperator technology as well as the possibility to increase the wing’s planform with minimal design impacts, the V-STAR™ is poised as an efficient, effective UAV with potential that extends its original logistics resupply design mission.

## References

- <sup>1</sup>Hirschberg, M. J., “V/STOL: The First Half-Century,” *American Helicopter Society*, URL: <http://www.aiaa.org/tc/vstol/VSTOL.html> [cited 22 December 2008].
- <sup>2</sup>“Fairey Rotodyne”, *Wikipedia*, Retrieved January 4, 2009, URL: <http://en.wikipedia.org/wiki/Rotodyne>
- <sup>3</sup>Roskam, J.R., *Airplane Design Part I: Preliminary Sizing of Airplanes*, Roskam Aviation and Engineering Corporation, Ottawa, 1985.
- <sup>4</sup>Walkovich, J., “Joined Wing Aircraft”, US Patent 3942747, March 9, 1976.
- <sup>5</sup>“Advanced Engine Concept Assessment”, US Army Research and Development Command, RDECOM TR 04-D-35, Contract Number DAAH10-03-C-0050.
- <sup>6</sup>“The USAF Stability and Control DATCOM, Volume I, Users Manual”, *McDonnell Douglas Astronautics Company*, St. Louis, 1979.

## Appendix A

Missions / Aircraft	V-STAR/UE	V-STAR/E	V-STAR/MAP	A-160	Little Bird	Eagle Eye	Fire Scout	Sikorsky X-2
<b>Endurance - ISR</b>								
Speed (knots)	153			70	78	120	60	120
Range (miles)	3570			1309	624	900	500	600
Payload (pounds)	110			300	300	200	300	500
Endurance (hours)	23.5			18.7	8	8	6	6
TOGW	2500	2413	2360	6500	3700	2250	3150	5,291
Cost (\$)	\$ 4,591,000	\$ 4,591,000	\$ 4,591,000	\$ 10,542,000	\$ 2,495,000	\$ 3,683,000	\$ 4,100,000	\$ 5,500,000
<b>Logistics</b>								
Speed			297	125	100	160	100	240
Range			1025	600	250	350	200	300
Payload			400	700	1000	200	600	500
Endurance			7	5.5	2.5	2	2	3
Cost			\$ 4,591,000	\$ 10,542,000	\$ 2,495,000	\$ 3,683,000	\$ 4,100,000	\$ 5,500,000
TOGW			2,372	6500	3700	2250	3150	5,291
Noise (db)			75	100	110	100	105	105
<b>Clandestine Re-Supply</b>								
Speed			297	125	100	160	100	240
Range			1025	600	250	350	200	300
Payload			400	700	1000	200	600	500
Endurance			7	5.5	2.5	2	2	3
Cost			\$ 4,591,000	\$ 10,542,000	\$ 2,495,000	\$ 3,683,000	\$ 4,100,000	\$ 5,500,000
TOGW			2,372	6500	3700	2250	3150	5,291
Noise (db)			75	100	110	100	105	105
<b>Hunter-Killer - HK</b>								
Speed		140		70	78	120	60	120
Range		2000		1309	624	900	500	600
Payload		300		300	300	200	300	300
Endurance		14.9		18.7	8	8	6	6
Cost		\$ 4,591,000		\$ 10,542,000	\$ 2,495,000	\$ 3,683,000	\$ 4,100,000	\$ 5,500,000
TOGW		2413		\$ 6,500	3700	\$ 2,250	\$ 3,150	\$ 5,291
<b>UCAV</b>								
Speed			297	125	100	160	100	240
Range			1025	600	250	350	200	300
Payload			400	700	1000	200	600	500
Endurance			7	5.5	2.5	2	2	3
Cost			\$ 4,591,000	\$ 10,542,000	\$ 2,495,000	\$ 3,683,000	\$ 4,100,000	\$ 5,500,000
TOGW			2,372	6500	3700	2250	3150	5,491
Noise (db)			75	100	110	100	105	105