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Development of Individual Lift (IL) technology over the last century has been sporadic and underwhelming, however, recent commercial investment has reinvigorated their potential. To embrace these promising developments in IL technology civilian and military proponents must first overcome skeptical views of ILDs. To achieve this, military institutions must conduct an impartial assessment of the feasibility of IL technology, consider the future role of ILDs in warfare, as well as develop methods to counter an adversary with an advantage in IL technology. The strengths of IL technology include its flexibility, low signature, and relatively low cost compared to existing aviation platforms. The opportunities for ILDs include advances in power technology and integration with other mobility platforms. These characteristics are sufficient to warrant further examination of ILDs military potential. This paper asserts that further examination will reveal that mature IL technology will enhance a military force's ability to conduct distributed maneuver, undermine anti-access/area-denial defenses, augment autonomous systems, and defeat adversaries in complex terrain.

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FUTURE WAR PAPER

Raising the Bar: The Future of Individual Lift Devices in Warfare.

**SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF OPERATIONAL STUDIES**

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PREFACE

In researching this essay I came upon the phrase “jetpack believers” to describe advocates or champions of Individual Lift Devices (ILDs). A reader doesn’t necessarily need to become a believer for this essay to achieve my aim. Instead, this essay aims to encourage military professionals to consider the merits of ILDs and make informed judgments on their role in future warfare. In this essay I have proposed that ILDs will enable future militaries to achieve a competitive advantage. To reap this reward military institutions must first conduct an impartial assessment of the potential of ILDs, unprejudiced by historical failings of IL technology, before reviewing the potential implications of this technology.

This essay would not have been possible without the support and guidance of industry, military, and academic professionals. Mr. David Mayman, the Chief Executive Officer of Jetpack Aviation, Mr. Greg Thompson, and Mr. Mark Butkiewicz from SURVICE Engineering each contributed to the research and development of this essay. I thank them for their time and their openness in sharing their experience. Colonel James Hammett of the Australian Army is a strong advocate of IL technology, having previously proposed military applications for ILDs. I am indebted for his support throughout the project, in particular for his concepts of ILD enabled amphibious operations. Lastly, my thanks go to Dr. Wray R. Johnson, Professor of Military History at the Marine Corps University School of Advanced Warfighting. Dr. Johnson’s enthusiasm and passion for clarity is infectious, and is hopefully reflected in this essay.

In *The Great American Jet Pack*, Steve Lehto asserts that the idea of personal flight is a mirage, continually escaping the clutch of technological advancement.¹ This essay assumes that this assertion is incorrect; instead, this essay claims that advancements in Individual Lift (IL) technology are bringing human flight into reality. Thus, military planners must better prepare for the integration of Individual Lift Devices (ILD) into existing systems, future programs, as well as develop methods to counter an adversary with an advantage in IL technology. Mature IL technology will enhance a military force's ability to conduct distributed maneuver, undermine Anti-Access/Area-Denial (A2/AD) defenses, augment autonomous systems, and defeat adversaries in complex terrain.

IL technology development over the last century has been sporadic and underwhelming. From 1940-1983, IL technology promised a revolution but delivered an impractical novelty. The expectations of flying shoes, platforms, ducted fan lift devices, rocket belts, and jet belts always exceeded reality.² Progress since 1983 has been unremarkable, with reduced corporate and military research into ILD. That said, sporadic, small-scale development has continued, primarily by entrepreneurs impassioned by popular science. In that regard, a resurgence in military and corporate investment is now apparent and has the potential to advance IL technology beyond science fiction. For promising international developments in IL technology to succeed, civilian and military proponents must overcome skeptical views of ILD.

There is a broad variety of technology that is categorized using the terminology of ILD. A generic definition will be used for the purposes of this essay, that is, *any physical device capable of propelling one or two soldiers within the air domain of a future battlespace*. This definition deliberately avoids limitations of control mechanisms, elevation limitations, payload,

and range requirements, to allow for a broad understanding of the impact of IL technology on warfare. Defining methods of ILD control is also relevant: kinesthetic control uses human body movement to direct the lateral control of an ILD, whereas electrically or mechanically controlled methods employ componentry to direct flight.

In 1958, the United States Army encouraged ILD research to augment soldiers' ability to jump and run. The Army sought a solution by "applying small rocket lift devices," requesting industry to create a backpack-mounted device to move 160lbs for more than fourteen-seconds.³ Respondents offered two divergent approaches. One employed short-burst rockets to cross obstacles; on the other hand, Bell Aerosystems advocated limited free flight and delivered a prototype capable of thirteen-second untethered flight. A subsequent review assessed Bell's project as "highly successful," but future potential was deemed limited by flight duration, noise, and specialist fuel requirements.⁴ Despite the project's cessation, Bell continued development and in 1965 secured funding for an alternative solution. The "Jetbelt" was a turbine rather than rocket-propelled device.⁵ Although not successful, development overseas offered renewed promise.

In 1960 a French company, Sud Aviation, applied to patent an "augmented thrust rocket system" that increased range by increasing fuel efficiency. In 1964 the French Army sponsored Sud to develop a prototype that enhanced soldiers' ability to "leap over obstacles." The requirements included moving 263lbs over "several hundred meters" below a fifty-meter ceiling. Despite successful tethered flights, Sud was unable to exceed forty-seconds of flight and concerns about noise led Sud to cease development.⁶ That said, concurrent advancements in turbojet and turbofan technology led other developers to pursue jet-powered ILDs.

In 1966 the Defense Advanced Research Projects Agency (DARPA) funded Bell and Williams Research to develop a new turbojet powered Jetbelt for the US Army. Bell withdrew from the program citing cost; a suitable engine alone would cost \$US85,000. Williams Research promoted the turbofan as an alternative to turbojet technology, convincing the United States Marine Corps (USMC) to support development under the Small Tactical Aerial Mobility Platform (STAMP) program.⁷ The Marines sought a “simple and highly reliable” low altitude platform to complement existing systems, lifting 500lbs over nineteen miles in thirty minutes.⁸ The platform was to be a conventionally fueled, helicopter transportable ILD with a mandated “emergency descent capability from low altitude.”⁹ It was also to be employable and serviceable by tactical units with limited training. Regrettably, tethered tests of the Williams Aerial Systems Platform (WASP) failed to meet design specifications and in 1973 the program was cancelled. Nevertheless, the Army pursued another ILD program, the Small Tactical Aerial Reconnaissance System-Visual (STARS-V).¹⁰

In 1977 the STARS-V program funded two simple and inexpensive WASP II prototypes.¹¹ Although capable of safe flight within the 15ft altitude test limits, fitment of a safety parachute capability, and an anticipated cost of \$250,000 per unit, by 1983 the WASP II prototypes did not meet expectations. Unfortunately, the Army’s requirement for simplicity of operation encouraged Williams to return to kinesthetic controls for the WASP II, resulting in a “directionally unstable” platform susceptible to wind gusts and requiring “extensive pilot compensation.” The prototype was too noisy, too expensive, and only capable of five minutes of flight.¹² And yet the Piasecki Aircraft Company proposed an alternative approach, one not selected for development but prominent in today’s ILD projects.

The Piasecki proposal employed “rotating combustion engine-ducted propeller[s],” that is, four ducted fans powered by twin, lightweight, low cost, low noise, and fuel-efficient engines. The Marine Corps rejected the proposal due to the complexity of the controls and aircraft weight. Moreover, it exceeded the payload, speed, altitude, and duration requirements.¹³ Nevertheless, the Piasecki proposal anticipated developments in current ILD technology, including the Malloy Aeronautics Tactical Reconnaissance Vehicle (TRV), sponsored by the US Army Research Laboratory (ARL) and currently undergoing testing and evaluation.¹⁴

Malloy originally developed the TRV as a “hoverbike” or “flying motorbike.”¹⁵ During feasibility and development testing it evolved into an unmanned logistical vehicle known as the Joint Tactical Aerial Resupply Vehicle (JTARV).¹⁶ The JTARV is a battery powered or gas-generated, electric-controlled, autonomous platform, propelled by four rotors with a 300lbs payload capacity.¹⁷ The initial idea was for this ILD to be unmanned; however, the potential for a platform capable of lifting several hundred pounds, coupled with an endorsed feasibility concept for a manned TRV, presents a significant advancement in IL technology.¹⁸ The TRV is just one example of a worldwide increase in ILD research and development.

Commercial developments demonstrate a resurgent global interest in ILDs. For example, Martin Industries is a publically listed New Zealand company that has produced advanced ducted-fan ILD technology. In an ongoing partnership with the Chinese Kuang Chi Corporation, they have successfully conducted manned and unmanned test flights of an Optionally Piloted Hovering Air Vehicle (OPHAV), achieving 265lbs of lift, 60 miles per hour in speed, and 30 minutes of flight.¹⁹ Dubai has funded the Chinese firm EHang to develop a drone-based aerial public transportation system using a German manufactured Volocopter as the basis for an Autonomous Air Taxi (AAT) system.²⁰ Dubai police have also undertaken a Memorandum of

Understanding with Russian developer Hoversurf to produce “hoverbikes” for emergency responders.²¹ In September 2017, Russian defense manufacturer Rostec announced its “flying car,” a battery-electric-powered, ducted rotary fan platform.²² Boeing has sponsored the *Go Fly* competition to develop “safe, quiet, ultra-compact, near-VTOL personal flying devices capable of flying twenty miles while carrying a single person.”²³ Jetpack Aviation has developed and tested autonomous and manned ILDs including jetpack and stand-on platform models. The US-based company has a Federal Aviation Authority (FAA) accepted turbine powered jetpack in production. They are designing a ducted fan model and an aerial resupply system, the Self Hauling Remote Payload Apparatus (SHRPA) and are working with the United States Special Operations Command (USSOCOM) under a Cooperative Research and Development Agreement (CRADA).²⁴ All of this development has not, however, engendered significant military interest, ideas, nor funding.

Legitimate skepticism derived from decades of over-promising and under-delivering IL technology remains an obstacle to a fair assessment of the military applications of IL. A realistic evaluation, however, should serve to remove continuing doubts. Current commercial developments in IL technology and ILD demonstrate the feasibility of this concept; therefore, a study of the military potential of ILDs (and development of counter-technologies) is warranted. Commercial investment has reinvigorated interest, propelling ILD from the realm of science-fiction to reality. Military institutions must therefore set aside historical skepticism, conduct an impartial assessment of the feasibility of IL technology, and consider the future role of ILD in warfare. ILDs enhance military capability in future warfare in four main areas: enhancing distributed maneuver; undermining an adversary’s A2/AD defenses; augmenting autonomous systems; and enhancing the ability to defeat adversaries in complex terrain.

ILDs will provide a competitive advantage to militaries that employ a distributed maneuver concept. The USMC Operating Concept (MOC) advocates distributed maneuver as it “avoid[s] the disadvantages of mass when required and employ[s] the benefits of mass when operationally favorable.”²⁵ The low signature and highly flexible nature of ILDs allow military forces to aggregate and disaggregate at speeds that exceed existing capabilities. This versatility can be used by reconnaissance forces to penetrate an enemy’s defenses without detection, or in advance force operations to seize initial objectives.²⁶ The force protection limitations of current ILDs prevents their use as main assault forces; however, limitations such as reduced armor protection does not preclude the use of ILD as a method of maneuvering assault forces toward an objective. An example is movement by ILDs from offshore vessels to intermediate transfer barges or to lightly defended objectives during amphibious operations. Another example is the movement of forces in rear echelon areas or to rendezvous with protected mobility platforms. ILDs can also be used to counter enemy A2/AD systems.

The USMC is developing the Expeditionary Advance Base Operations (EABO) concept as part of its efforts to defeat an adversary A2/AD system. The EABO concept aspires to breach an adversary’s defenses yet minimize the vulnerability of concentrated forces.²⁷ EABO employs “mobile, relatively low-cost capabilities in austere temporary locations forward as integral elements of fleet operations.”²⁸ The characteristics of ILDs are not only suitable for this approach, but they are also near synonymous. ILDs are highly mobile, whether defined as their ability to deploy to an advance base, or be employed from one. They are exceptionally low cost when compared to existing ground and air movement systems. Finally, their ability to operate without an extensive maintenance and supply infrastructure ensures their suitability for working in austere environments. These characteristics should attract military planners to the benefits of

IL technology. IL technology advancements also demonstrate the potential for ILD to augment autonomous systems.

Autonomous systems such as drones, pilotless aircraft, and robotic ground clearance devices risk materiel rather than personnel. Instead of artillery or aviation bombardment, an offensive maneuver in future warfare may commence with a massed attack of armed drones employing swarm tactics. Inherently dangerous tasks such as mine clearance operations may well be conducted using mechatronic devices and routine functions such as route control may be performed by artificially intelligent robots. Regardless of these advancements, the human factor of warfare will remain and therefore humans, or more accurately soldiers, will need to maneuver in the battlespace. This combination of human performance and the advantages of autonomous or robotic systems is called Manned-Unmanned Teaming (MUMT). ILDs can be integrated, using the MUMT concept, alongside drones, or ground clearance robotics. At its broadest, ILDs could be employed as a redundancy option in case of major system or infrastructure collapse. As an example, a small team of operators using ILDs could maneuver with reduced chance of detection and faster than rotary-wing aircraft, establishing a local network less susceptible to enemy interdiction than remote systems, and control fires from external platforms or a stand-alone system such as Tactical Loitering Air Munitions (TLAM). Use of autonomous systems will be prolific in the complex terrain of the future battlespace.

A global trend towards population centers in littoral regions and the emergence of megacities presents the final area to be explored for the generic military application of IL technology. ILDs can assist militaries in this complex urban and littoral terrain. They can be employed by a maneuver force to rapidly isolate an objective. The size of ILDs enables them to operate in areas of urban clutter beyond the reach of rotary-wing aircraft and to achieve

simultaneous landings in areas unsuitable for larger craft. The maneuverability of ILDs enables horizontal and vertical envelopment inside the urban terrain, maneuvering above and around infrastructure such as high-rise buildings. ILDs also provide a pervasive and individual medical evacuation capability that exceeds the reach and speed of other air and ground assets. Similar benefits apply in littoral regions. In addition, ILDs are unrestricted by ground obstacles such as marshlands, tidal variance, inadequate or absent port facilities. ILDs ability to rapidly insert and extract is a significant advantage that developers are promoting, amongst other benefits.

Examining employment of ILDs from a commercial perspective can further illuminate the possibilities as well as challenges of incorporating ILDs in warfare. Of the multitude of companies introduced earlier in this essay, the Molloy Aeronautics JTARV is a prominent example of advancements in IL technology. Its developers strike a balance between optimism and realism that was not evident in claims of some earlier-generation developers. Greg Thompson and Mark Butkiewicz from SURVICE Engineering, a US-based Department of Defence engineering firm and partner with Malloy Aeronautics, identify the JTARV as a complementary asset to existing military capability that increases options for the last leg of the logistics chain. It doesn't replace the airplane, helicopter, or truck; it provides an alternative for "the last mile." Despite their success to date, integration with existing systems to ensure the control of large drones amid other manned and unmanned aircraft is an important issue for current airspace deconfliction that will only increase. While the developers don't foresee technical hurdles to achieving manned flight using the JTARV they are realistic about the challenges that transition to an ILD would encounter, and thus have been focused on unmanned uses of the platform.²⁹

Mr. Thompson and Mr. Butkiewicz identify two primary constraints to the employment of ILDs: safety and conceptual aversion. The fundamental issue is safety. Fixed-wing aircraft can glide, rotary-wing aircraft can auto-rotate, both allowing an element of survivability during an emergency or crash landing. Parachutes were included in the WASP II project, however they are considered an emergency precaution rather than an inherent redundancy measure. ILD platforms would likely need a level of redundancy to be approved for manned flight. The second issue is conceptual aversion, primarily by political and military decision-makers. This aversion likely results from the safety and survivability issues already identified, magnified by a credibility gap generated by decades of failed promises rather than proven capability. Mr. Thompson recognized that, while technology can be quickly developed, implementation will likely be gradual, and the more significant challenge will be a “paradigm shift to overcome inertia.”³⁰

The Chief Executive Officer of Jetpack Aviation (JPA), David Mayman, has also demonstrated a cautious and pragmatic optimism regarding the potential for ILDs. His restrained enthusiasm, however, contrasts with the leading-edge progress of JPA jetpacks. As introduced earlier, this US-based company has developed and tested individual lift devices that “fly faster than any helicopter and produce a lower heat signature” and have passed FAA certification requirements. The JPA Jetpack, JumpJet, and load carrying SHRPA models all have multiple redundancy features. These include the ability to maintain flight with one or more motors inoperable and redundant wiring and control signals, thus countering an enduring criticism of ILD safety. Mr. Mayman notes that military developers desire ballistic protection, noise reduction, and the possibility of weaponizing ILDs. These are significant aspirations for a capability that has been dismissed for decades.³¹

Having provided an overview of some generic military applications for IL technology, it is useful to explore the implications of military employment of ILD using the “SWOT” market analysis framework. SWOT is a strategic business planning tool that examines the Strengths, Weaknesses, Opportunities, and Threats to a business or market. It originated with a Stanford University research project that aimed to identify reasons for corporate failure.³² Strengths and weaknesses are the positive and negative components that can be controlled or influenced. Opportunities and threats are the positive and negative components that cannot be controlled.

According to the SWOT framework primary strengths of IL technology are its flexibility, low signature, and relatively low cost compared to existing aviation platforms. There are many factors that contribute to the flexibility of ILDs. Most importantly, ILDs multiply maneuver options by the lowest divisible level: the individual. Additionally, the small size of many ILDs creates force deployment opportunities not feasible with other platforms. ILDs can be bulk transported by air, sea, and ground routes, or self-deploy in autonomous or manned modes. Small ILDs can be retained, air-dropped, or self-deployed as personal extraction devices. They can be incorporated into protected mobility platforms, either as an aid to maneuver or as an extraction method comparable to a pilot’s ejection platform. ILDs can be used in Foreign Humanitarian Assistance (FHA) and Disaster Relief (DR) operations, either alone or in conjunction with unmanned logistics platforms. ILDs can be employed from sea-based platforms as part of amphibious operations, from the ground, or, with further development, launched from airborne platforms as a controllable and maneuverable capability. The ability to rapidly maneuver and bypass obstacles makes ILDs highly suitable for gap crossing operations, either as part of a security force or as the primary method for crossing gaps and obstacles. ILDs also have the advantage of small detection “signatures.”

The Marines Operating Concept identifies the “battle of signatures” as one of five key drivers of change in the future operating environment of 2015-2025.³³ The signature of ILDs makes them less vulnerable to detection than existing major platforms and therefore creates an advantage for militaries who adopt them as part of their capability mix. There is no requirement for ILDs operating by pilot control to emit electronic signals, they present a small heat signature, and manned platforms can be masked within a fleet of unmanned systems. ILD operators can employ terrain masking tactics or disperse in complex terrain to avoid detection. Flexible employment options and reduced signature incur a cost, but in the case of ILDs that cost does not appear to be financial.

ILDs are a significantly more cost-effective capability than existing methods of aerial insertion and extraction. A 2011 proposal by Lieutenant Colonel James Hammett of the Australian Army highlighted the starkness of this cost comparison: the price of one multi-role helicopter equated to approximately 500 Martin Aircraft Jetpacks.³⁴ This cost comparison would be starker once sustainment and training costs are included in the comparison. The WASP II prototypes developed by the US STARS-V program relied on kinesthetic controls and required skill and extensive pilot training. By contrast, it is relatively inexpensive to teach a soldier to operate a modern ILD. For example, JPA recently trained USSOCOM members to operate their Jetpacks within a week and one of their models can be operated with even less training.³⁵ Advances in simulated training will only reduce the costs of money and time. A purely numerical analysis does not, however, account for the intangible benefits of rotary-wing aviation and the most significant of these is reduced risk.

Airworthiness standards have lowered the risk to personnel but also restricted the flexibility of rotary-wing aviation. The often exorbitant and rising cost of air mobility platforms

reduces the willingness of commanders to employ these high-value assets in a contested battlespace. Casualty evacuation is an example. The decision to employ casualty evacuation aircraft requires analysis of the risk to aircraft, aircrew, and medical personnel, all three of which are finite and expensive military assets. Casualty evacuation and movement of medical personnel by ILD reduces the risk equation and can enhance casualty evacuation rates. In short, ILDs enhanced with sufficient redundancy measures and protection are risk-worthy and can therefore be employed on the battlefield of the future. That said, ILDs have weaknesses that must be mitigated.

The primary weaknesses of ILDs are reduced force protection, airspace de-confliction, and technical limitations of ILD such as noise levels. Despite the progress of IL technology, these weaknesses are significant and must be mitigated or accepted as risk. The most notable of these risks is force protection. Notably, a decision to adopt ILD could be perceived as contrary to the protected mobility approach. Protected mobility is the safeguarding of personnel en-route to and on the battlefield. Commanders accept degraded situational awareness, route limitations, and the concentration of forces in order to reduce their forces's exposure to the physical dangers of battle. The lift capacity of current ILDs precludes the fitment of armor and other protection that is afforded to rotary-wing aircraft. As a result, ILDs are vulnerable to direct fire. This weakness may be mitigated but is unlikely to be overcome in the near term.

Yet force protection is more than the ability to withstand direct fire; in fact, a more effective approach to force protection would be to avoid detection where possible. It is in this area that ILD can mitigate their vulnerabilities. Forces inserted via ILD are smaller and less detectable. They are therefore harder to identify, track, and target. ILDs can operate at altitudes beyond the accurate range of small arms fire and yet able to maneuver in complex terrain,

limiting the effectiveness of air-to-air weapons. Despite efforts to mitigate these risks, any ILD concept for employment will be challenged by force protection requirements and the associated trend toward autonomous technology. Although this trend is pervasive, the possibility of a battlefield devoid of humans within the next fifteen years is unlikely.

Another weakness of ILDs is airspace de-confliction. Airspace de-confliction is the coordination of aviation platforms with each other and with above-surface fires. The employment of ILDs will add to the challenges that the proliferation of manned and unmanned aircraft and the increased range of surface-generated fires has already created. Adding ILDs to the airspace will add challenges that are not currently present in the coordination of unmanned aircraft and ground-based fires. While it is true that a Soldier or Marine can be trained to operate one of the current model ILDs within a week, it is unrealistic to expect the same competency in airspace awareness of a rated pilot, regardless of additional training time. Methods of airspace coordination must therefore be designed to meet this shortfall. Technical methods may work. For example, ILDs could be limited to below a predetermined coordinating altitude or prevented from entering a restricted zone. An alternative method is the integration of a tracking system to control fires away from an ILD force. Despite mitigation efforts and regardless of whether IL technology is realized, the problem of airspace de-confliction will remain a challenge for the future battlespace.

Another continuing challenge for IL technology is noise, particularly in turbine powered ILDs. For example, the Martin Industries Jetpack produces 90dB at full throttle.³⁶ Noise therefore becomes a force protection issue for operators and other personnel, including non-combatants, and may limit the flexibility of ILDs in some non-combat roles such as FHA/DR. Thus, noise attenuation must be a priority for ILD developers. If further noise reduction is

unachievable then noise must be countered, mitigated, or used to advantage. This includes the masking of sound by terrain or route selection, or by the use of noise to induce fear in an adversary. Having considered the weaknesses of IL technology, it is only appropriate to analyze the opportunities.

The primary opportunities for ILDs are advances in alternative power technology and integration with surface and subsurface individual mobility platforms. Thrust, or more accurately the ratio between thrust and weight, is the most significant factor in developing IL technology. The examples outlined in this essay have each advanced a particular method of power generation, such as turbojet or turbofan. Some of these efforts have been industry leaders, such as the Martin Aircraft motor that generates more efficient thrust than the Joint Strike Fighter.³⁷ Global improvements in battery storage and weight reduction have created opportunities for electric-powered ILDs. Engine refinements have increased the lift capacity, flight duration, fuel efficiency, and most importantly, safety of flight. Further advancements will only increase this evolution. An example is the MyT engine, a non-reciprocating internal combustion engine that claims significantly higher power to weight output than conventional motors. The MyT offers an additional advantage in its suitability as a single engine type for a variety of mobility platforms.³⁸ This level of integration leads to the second opportunity, that of integration with other surface or subsurface mobility platforms.

The opportunities for ILD cannot be considered in isolation. Instead, they should be considered as part of a broader approach to mobility. Current military mobility platforms are mainly restricted to a singular domain. Planes fly in the air, armored vehicles maneuver on land, and naval vessels navigate the world's waters. The USMC Landing Craft Air Cushion (LCAC) is an example of technology that has breached these geographic barriers. Another example is the

USMC MV-22 Osprey that extends Marines operational reach by combining the benefits of vertical lift and forward propulsion. Pioneering individual mobility solutions are not as revolutionary; however, Gibbs Sports Amphibians manufacture an exemplar product that could be employed to enable personal mobility on sea and land. The “Quadski” is a single platform capable of 45 mph speeds on water and land.³⁹ An opportunity exists for ILD developers to integrate platforms that enable maneuver between and within these domains and therefore create a competitive advantage over adversaries. An example is the combination of the aerial insertion capability of an ILD with the ground maneuver capability of a tracked “Segway” type vehicle.⁴⁰ A more ambitious aim would be the integration of exoskeletons.

Development of an exoskeleton with integrated lift capacity would revolutionize individual mobility on the battlefield. An exoskeleton is a physical structure that protects and enhances the capabilities of the Soldier or Marine. An exoskeleton could either contain IL technology or be capable of integrating with an ILD. By maintaining a separate, yet integrated ILD, the operator could maneuver on the surface and employ the ILD as organic aerial observation, fire support, and lift capability. Technology to realize this capability, including Artificial Intelligence (AI), autonomous flight control, and, as outlined, power generation technology, is progressing independently. For the last component, it is realistic to assume that advancements in power generation will increase the lift capacity of existing ILDs to a stage where they are capable of lifting an exoskeleton. Current developments in turbine technology with the potential to lift 700lbs draws this science-fiction image toward reality.⁴¹ Such improvements would not only be the realization of individual mobility, but of protected and enhanced individual mobility. The opportunities for military use of ILDs are momentous; however, the threats to military adoption of IL technology are significant and enduring.

Threats to military adoption of IL technology include organizational and societal risk tolerance and the impact of adversary development of counter-ILD technology. Of these, the acceptance of risk is the most important. National and military leaders employ their limited military capabilities judiciously, and of these limited capabilities it is the human capacity that is the most valuable. Therefore, it would be unrealistic and unwise to expect leaders to employ their scarce resource in untested or high-risk technology; like the airplane before World War One. The threat to military adoption of ILD is that this political and military aversion is entrenched, restricted by the paradigm of protected mobility, and that memories of IL technology failures in the past impede a fair assessment of its potential. The only credible counteraction to this threat is the impartial demonstration and testing of ILD capability and potential, for which defense scientific organizations must play a crucial role. Defense scientists are well placed to test the claims of ILD developers and promote the significant industry achievements that have occurred since the days of dangerous and ineffective hydrogen-peroxide jetbelts.

An adversary's development of counter-ILD technology poses a credible threat that may arise out of counter-drone or anti-aircraft technology. Examples of counter-ILD technologies include directed energy and direct fire weapons, landing area denial, and electronic attack. If ILDs remain limited to private and commercial use then developers have little incentive to develop counter-technologies aside from meeting regulatory and public security requirements. Militaries that adopt ILDs must therefore concurrently develop methods to counter adversarial capabilities. As with other technology, the benefit of early adoption is often associated with an enduring competitive advantage.

Developers have advanced IL technology and the commercial potential is apparent. Dubai's plans for emergency and passenger transport using "hoverbikes" and autonomous

aviation platforms are enabled by Russian commercial developers. The revolutionary achievements of New Zealand-based Martin Industries are now being jointly developed with a Chinese organization. Military competitors are pursuing these technologies including development of a Russian “hoverbike.” The US Army Research Laboratories support for the Malloy Aeronautics JTARV and the USSOCOM agreements with Jetpack Aviation are positive steps toward recognizing the potential for ILDs but the tempo and scope of these projects must be expanded if these technologies are to be fully realized. The USMC STAMP program is a model for military planners and defense scientists to emulate. The Marines established a vision for military ILDs, engaged and funded a leading commercial firm to develop a prototype, and engaged with other services for collaborative research. The difference for today’s Individual Lift champion is that the technology now matches the vision and the only way is up.

In conclusion, significant advances in IL technology present an opportunity to integrate ILDs into future military capability. ILDs will enhance a military force’s ability to conduct distributed maneuver, undermine adversary A2/AD defenses, augment autonomous systems, and defeat adversaries in complex terrain. These are significant benefits that must be considered impartially. Organizational barriers related to risk tolerance must be overcome by reframing the potential of ILDs. The strengths and opportunities afforded by ILDs are sufficient to warrant further examination of their military potential.

Endnotes

¹ Steve Lehto, *The Great American Jet Pack: The Quest for the Ultimate Individual Lift Device* (Chicago: Chicago Review Press Incorporated, 2013), 176.

² *Ibid.*, 3, 156-163.

³ Bernard Lindenbaum, *V/STOL Concepts and Developed Aircraft. Vol I – A Historical Report (1940-1986)* (Ohio: Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, study conducted by Universal Energy Systems), 1986.

<http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA175379>, 2-1.

⁴ *Ibid.*, 2-12-2-28.

⁵ Lehto, *The Great American Jet Pack*, 75-92.

⁶ Lindenbaum, *V/STOL Concepts and Developed Aircraft*, 2-46 – 2-61. Although the noise of the Sud *Ludion* was considerable, it was significantly less than the Bell model concurrently under development.

⁷ *Ibid.*, 3-14 – 3-30.

⁸ *Ibid.*, 3-31 – 3-38. The Marines' concept for employment indicated it should fly "among the tree trunks, beneath the forest canopy, taking advantage of the cover and concealment afforded by the natural environment—actually pushing aside or penetrating frangible vegetation, landing and taking off in spaces too small to accommodate a helicopter even the in the absence of barriers to access." The USMC STAMP program operated on a shoestring budget, allocated only \$2.18 million from 1970-74 to design, develop, and deliver a tested prototype. Its notable difference from the subsequent US Army STARS-V program was that it was required to lift two people.

⁹ *Ibid.*, 3-38.

¹⁰ *Ibid.*, 3-38 – 3-40.

¹¹ *Ibid.*, The US Army leveraged the WASP research already conducted by Williams International under the STAMP program to conduct the STARS-V program with an equally small \$2.54 million budget. The Army program requirement under STARS-V was articulated as "We are not looking for a weapons carrier or a load carrying device. We are simply looking for a one-man conveyance, without rotor blades, which can move safely in constricted spaces, can communicate by means of FM radio and can be operated by essentially untrained or quickly trained, run-of-the-mill, unit personnel. If it requires a certified pilot or long training, we are not interested. We would see company executive officers, Battalion S-3, Battalion and Brigade Liaison Officers using these devices for coordination, liaison, battle position reconnaissance and troop leading."

¹² *Ibid.*, 3-39 – 3-58.

¹³ *Ibid.*, 3-101 – 3-114.

¹⁴ Mark Prigg, "US Soldiers Could Soon Travel Like Stormtroopers: Military Bosses Developing Star Wars 'Hoverbikes' For The Battlefield," *Daily Mail (UK)*, last modified June 15, 2015, <http://www.dailymail.co.uk/sciencetech/article-3125412/US-soldiers-soon-travel-like-stormtroopers-Military-bosses-developing-Star-Wars-hoverbikes-soldiers.html>.

¹⁵ "Buzzcraft," *United States Army Acquisition, Logistics, and Technology*, October 2015, <https://search-proquest-com.lomc.idm.oclc.org/docview/1732603867?accountid=14746>, 203-204.

¹⁶ Greg Thompson and Mark Butkiewicz, telephone interview with senior management of SURVICE Engineering, October 03, 2017.

¹⁷ Douglas Ernst, "Army 'hoverbike' prototype with 300-pound payload capacity passes key test," *The Washington Times*, January 18, 2017, <http://www.washingtontimes.com/news/2017/jan/18/army-hoverbike-prototype-with-300-pound-payload-ca/>.

¹⁸ David McNally, "Army Flies 'Hoverbike' Prototype," *United States Army*, last modified January 17, 2017, <https://www.army.mil/article/180682>.

¹⁹ Martin Jetpack, last accessed November 02, 2017, <http://www.martinjetpack.com/sales/manned-jetpack0.html>. The flight time is limited by Federal Aviation Authority (FAA) fuel capacity regulations.

²⁰ Sarah Clemence, "Dubai Stages First Public Test of Drone Taxis," *Bloomberg Pursuits*, September 26, 2017, <https://www.bloomberg.com/news/articles/2017-09-26/dubai-stages-first-public-test-of-volocopter-drone-taxi>.

²¹ "Dubai Police Announce Star Wars-style Hoverbikes For Officers at Gitex Tech Conference," *Australian Broadcasting Corporation*, October 14, 2017, <http://mobile.abc.net.au/news/2017-10-14/dubai-police-announce-star-wars-style-hoverbikes-for-officers/9049860?pfmredir=sm>. "The Hoversurf Scorpion... Russian-made craft can fly at a height of five metres and carry a police officer over congested traffic in emergency situations... The bike can also fly without a passenger and can go up to six kilometers... It can fly for 25 minutes and can carry up to 300kg of weight at a speed of 70kph."

²² Kyle Mizokami, "Kalashnikov Unveils Flying 'Hovercycle'," *Popular Mechanics*, September 26, 2017, <http://www.popularmechanics.com/military/aviation/a28397/kalashnikov-hovercycle/?src=socialflowTW>.

²³ Boeing "Go Fly" competition website, last accessed November 02, 2017, <http://goflyprize.com/how-it-works/>. VTOL is Vertical Take-Off and Landing, a capability employed by rotary-wing and some fixed-wing aviation platforms.

²⁴ David Mayman, interview with Chief Executive Officer of Jetpack Aviation, December 11, 2017; Jetpack Aviation, last accessed December 18, 2017, <http://www.jetpackaviation.com/military/>.

²⁵ Headquarters US Marine Corps, *Marine Corps Operating Concept* (Washington, D.C.: Headquarters US Marine Corps, September 2016), 16.

²⁶ Colonel James Hammett, Australian Army, interview, November 03, 2017; Lieutenant Colonel James Hammett, "Starship Troopers – A Reality?" Unpublished paper, last modified 2012, Microsoft Word File.

²⁷ Matthew Clapperton, "USMC outlines 'Inside Force' concept", *Janes International Defense Review*, October 28, 2017, <http://www.janes.com/article/75228/usmc-outlines-inside-force-concept>.

²⁸ Lee Hudson, "Navy, USMC intend to release Expeditionary Advanced Base Ops Concept," *Inside Defense*, October 13, 2017, <https://insidedefense.com/inside-navy/navy-usmc-intend-release-expeditionary-advanced-base-ops-concept>.

²⁹ Greg Thompson and Mark Butkiewicz, telephone interview with senior management of SURVICE Engineering, October 03, 2017.

³⁰ *Ibid.*

³¹ David Mayman, interview with Chief Executive Officer of Jetpack Aviation, December 11, 2017.

³² Mike Morrison, “SWOT Analysis made simple,” *Rapidbi* (blog), April 20, 2016, <https://rapidbi.com/swotanalysis/>.

³³ Headquarters US Marine Corps, *Marine Corps Operating Concept* (Washington, D.C.: Headquarters US Marine Corps, September 2016), 5.

³⁴ Lieutenant Colonel James Hammett, “Starship Troopers – A Reality?” Hammett approximated the cost of one MRH-90 at AUD\$51 Million and the Martin Industries Jetpack was estimated at under AUD\$100,000.

³⁵ David Mayman, interview with Chief Executive Officer of Jetpack Aviation, December 11, 2017.

³⁶ Colonel James Hammett, interview, November 03, 2017.

³⁷ *Ibid.*, The two thrust fans of the 2011 Martin Industries Jetpack achieved 92% efficiency, compared to the Joint Strike Fighter at 82%.

³⁸ Lieutenant Colonel Brett Laboo, “The Massive Yet-Tiny Engine: A comparison of OEM claims”, *Australian Army Land Warfare Conference*, October 2012, https://pesn.com/archive/2012/11/21/9602227_Australian_DOD_Comparative_Analysis_Places_MYT_Engine_in_Top_Position/report.htm.

³⁹ Gibbs Sport Amphibians, last accessed November 03, 2017, <https://www.gibbssports.com/quadski>.

⁴⁰ Segway, last accessed December 19, 2017, <http://www.segway.com/>.

⁴¹ David Mayman, interview with Chief Executive Officer of Jetpack Aviation, December 11, 2017.

Bibliography

- Australian Broadcasting Corporation. "Dubai Police Announce Star Wars-Style Hoverbikes For Officers at Gitex Tech Conference." *Australian Broadcasting Corporation*. October 14, 2017. <http://mobile.abc.net.au/news/2017-10-14/dubai-police-announce-star-wars-style-hoverbikes-for-officers/9049860?pfmredir=sm>.
- Clapperton, Matthew. "USMC Outlines 'Inside Force' Concept." *Janes International Defense Review*. October 28, 2017. <http://www.janes.com/article/75228/usmc-outlines-inside-force-concept>.
- Clemence, Sarah. "Dubai Stages First Public Test of Drone Taxis." *Bloomberg Pursuits*, September 26, 2017. <https://www.bloomberg.com/news/articles/2017-09-26/dubai-stages-first-public-test-of-volocopter-drone-taxi>.
- Corbett, Arthur. "*Expeditionary Advance Base Operations Concept: Considerations for Force Development*." (Draft, email correspondence and discussion August 2016 and November 2017)
- Ernst, Douglas. "Army 'Hoverbike' Prototype With 300-Pound Payload Capacity Passes Key Test." *The Washington Times*. January 18, 2017. <http://www.washingtontimes.com/news/2017/jan/18/army-hoverbike-prototype-with-300-pound-payload-ca/>.
- Hammett, James. "Starship Troopers – A Reality?" Unpublished paper, last modified 2012. Microsoft Word File.
- Headquarters US Marine Corps. *Marine Corps Operating Concept*. Washington, D.C: Headquarters US Marine Corps, September, 2016.
- Hudson, Lee. "Navy, USMC Intend To Release Expeditionary Advanced Base Ops Concept." *Inside Defense*. October 13, 2017. <https://insidedefense.com/inside-navy/navy-usmc-intend-release-expeditionary-advanced-base-ops-concept>.
- Laboo, Brett. "The Massive Yet-Tiny Engine: A Comparison Of OEM Claims." *Australian Army Land Warfare Conference*. October 2012. https://pesn.com/archive/2012/11/21/9602227_Australian_DOD_Comparative_Analysis_Places_MYT_Engine_in_Top_Position/report.htm.
- Lehto, Steve. *The Great American Jet Pack: The Quest for the Ultimate Individual Lift Device*. Chicago: Chicago Review Press Incorporated, 2013.

Lindenbaum, Bernard. *V/STOL Concepts and Developed Aircraft*. Vol I – *A Historical Report (1940-1986)*. Ohio: Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, study completed by Universal Energy Systems, 1986.
<http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA175379>

McNally, David. “Army Flies ‘Hoverbike’ Prototype.” *United States Army*. January 17, 2017, <https://www.army.mil/article/180682>.

Mizokami, Kyle. “Kalashnikov Unveils Flying ‘Hovercycle.’” *Popular Mechanics*. September 26, 2017. <http://www.popularmechanics.com/military/aviation/a28397/kalashnikov-hovercycle/?src=socialflowTW>.

Morrison, Mike. “SWOT Analysis Made Simple.” *Rapidbi*, (blog). April 20, 2016. <https://rapidbi.com/swotanalysis/>.

Prigg, Mark. “US Soldiers Could Soon Travel Like Stormtroopers: Military Bosses Developing Star Wars ‘Hoverbikes’ For The Battlefield.” *Daily Mail (UK)*. June 15, 2015. <http://www.dailymail.co.uk/sciencetech/article-3125412/US-soldiers-soon-travel-like-stormtroopers-Military-bosses-developing-Star-Wars-hoverbikes-soldiers.html>

United States Army. “Buzzcraft.” *United States Army Acquisition, Logistics, and Technology*. October 2015. <https://search-proquest-com.lomc.idm.oclc.org/docview/1732603867?accountid=14746>.