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15 JAN 2014

THREE DIMENSIONAL (3D) PRINTING IN AVIATION: HOPE FOR BREAKING THE LOGISTICS SHACKLES

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Aircraft are very complex machines. A modern aircraft is made up of tens of thousands of parts some very small and others quite large. Correct functioning of an aircraft requires all these different parts to mesh together and work in concert. A modern fighter aircraft can truly be said to be a system of systems. High performance fighter aircraft often push available technology to its limits in order to achieve required performance. When a component is operating at its limits it is reasonable to expect a higher rate of failures than when a component is operated in the middle of its capability range. In order to maintain effectiveness, components that fail or that does not perform up to desired levels need to be changed. The maintenance of a modern aircraft, whether a fixed or a rotary wing machine, intended for combat or support tasks, requires a very large number of components and parts to be available at the field location of the machine with no room for error. Absence of and even delays in availability of even very small components such as a washer / seal or screw that costs only a few rupees can deny availability of the aircraft for a mission.

The Logistics Shackles

Most modern aircraft follow a Line Replaceable Unit (LRU) concept wherein on finding a failure first line service personnel remove the faulty LRU and replace it with a serviceable LRU of the same specification. The unserviceable LRU is back loaded to a repair agency located in the hinterland for repair and return to the line unit[i]. Such a system requires a reasonable stock of all critical components to be maintained at the line unit. In

addition, reliable and quick means of communication should be available from the field unit's location till the repair agency. The repair agency's efficiency in repairing LRUs and feeding them forward is also a factor in the maintainability and sustainability of aircraft units. Any disruption in the availability of LRUs and in the lines of communication to the repair agency can have a major adverse affect on availability of aircraft[ii]. In cases where the aircraft is imported and the LRU repair agency is located in another country the situation becomes more complex. The time lags in the system now increase with larger delays in unserviceable aircraft becoming available for use. The alternative system of repairing all components at the line base where the aircraft are based requires setting up of very complicated, expensive and manpower intensive repair labs at the field location(s). For a variety of reasons this is not feasible on a large scale for multiple types of aircraft.

Thus logistics issues are able to affect combat availability of military forces in a major manner. The setting up of repair facilities close to field units is very costly and multiple such facilities would be required near all the geographically dispersed locations where a type of aircraft operates. Moreover such facilities would be required for all the different types of aircraft operated. Such forward located repair agencies are likely to be important centres of gravity for enemy attack. The chain feeding unserviceable LRUs to and from a central repair agency located deep within friendly territory requires multiple quick communication lines from field units to the repair agency. In the LRU concept field units require to stock a predefined level of LRUs to cater for immediate needs which adds to the cost. A cost effective and efficient solution has been sought by planners for a long time. Organisational solutions have included the shift from dedicated on site repair agencies toward a LRU system; such organisational solutions have not been able to fully address the problem though they have mitigated the problem to an extent. Now however, a technology developed in the civil realm, that of 3D printing, holds the promise of being able to address the maintainability and sustainability problem faced by aviation forces everywhere. While air forces are able to cater for this logistics problem somewhat better due to their fixed base locations the problems are exacerbated for army aviation units which move with mechanised forces and for naval aviation based on aircraft carriers that are on patrol far

from the nearest friendly port. The logistics problem exists for the purely land based equipment of the army as well as on-ship equipment in case of navies.

3D Printing Technology and Manufacturing

The concept of 3D printing[iii]revolves around making 3D articles through use of printers derived from the ubiquitous ink jet printers. In the civil field this concept has been developed progressively for use in the manufacturing as well as medical fields. Printing of complex shapes in plastic has been achieved through use of "ink" containers that are filled with plastic compounds in liquid form for the printing. 3D printers work through applying progressive thin layers of plastic, or the contents of their ink tanks, to build up a three dimensional object through accretion. Through suitable modifications revolving around developing "inks" of suitable metals in liquid form / suspension, metallic 3D printing has also been demonstrated. Originally seen as a novelty the practical applications of this new technology soon became apparent. The great flexibility obtained from this technology is apparent to anyone looking at the manufacturing processes in use today. Production technology has moved from customised production to mass production to customised mass production through application of ever newer concepts and information technology to the manufacturing process. 3D printing brings a new concept of decentralised manufacturing to life possibility as the model for manufacturing for the future. A gun printed through use of a 3D printer was used to fire at least fifty bullets in November –December 2013[iv]. This demonstration brings out the practical utility of use of 3D printers to make even small arms[v]. The products that can be made through use of 3D printing should be limited only by availability of digitised designs and blueprints, availability of "inks" that comprise the required material needed for the parts to be manufactured and the physical size of the printer.

3D Printing for the Military Forces: A Possible Logistics Panacea

In the military domain 3D printing opens up the possibility of freeing military forces from the tyranny of logistics supply lines through empowering the production of required spares and supplies at the site where they are required if digitised designs and blueprints and the needed raw material in the form of "inks" are available at the concerned location.

This technology is by no means a mature technology as on date. Developments are being pursued in this field in research laboratories around the world. As a proof of concept and reliability of parts manufactured through 3D printing it was reported on the BBC website on 05 January 2014 that a British Royal Air Force (RAF) Tornado Interdictor / Strike (IDS) fighter aircraft recently flew using parts printed on 3D printers[vi]. Such a demonstration paves the way for wider acceptance of the output of 3D printers in aircraft. This bolstering of confidence is needed in view of the virtual absence of margins of error in aviation; coupled with the human resistance to new things when the traditional objects are doing the job just fine. It should be kept in mind that the failure of a very small and low cost part in flight can potentially bring an aircraft down[vii]. It can reasonably be expected that in contrast to the relatively low risk parts used in the RAF demonstration mentioned above, increasingly complex and more important parts will be tested on aircraft in the years ahead in order to prove the concept and help it progress towards operational utilisation.

In the foreseeable future it is conceivable that it will be possible to manufacture a large variety of complex products at different locations through this technology. As a nation that aspires towards greater growth it behoves India to pursue this new technology to help overcome the missed opportunity of the industrial revolution through leveraging its information technology (IT) skills and competence to be a pioneer in the coming "information based manufacturing" era. 3D printing could be the new manufacturing miracle after the assembly line based mass production systems that helped industrially advanced nations to develop. Given the possibility offered by 3D printing in the realm of logistics of cutting supply side constraints it is equally important for the armed forces to undertake serious research into this technology in institutes of higher learning and in-house to help progress towards a more efficient way of maintaining and sustaining their combat forces.

Conclusion

Logistics involving ensuring that the right equipment is available at the right time at the right place and in the hands of the right combatants has been a military necessity since organised military forces first came to be deployed. Creating of logistics lines of supply

creates new vulnerabilities for military forces. In the case of naval units required supplies and spares would require to be carried along due to absence of viable quick resupply options. In the case of imported equipment fairly large stocks of spares and supplies would have to be maintained against their possible need in wartime. The latest development in the field of printing technology is development of 3D printers able to print out complex shapes through use of special "inks" using basically modified inkjet printer technology. Further developments of such printers hold forth the possibility of freeing military forces from the tyranny of logistics lines of communication through enabling field forces to print what they need on demand. It would be prudent for the Indian Armed Forces to pursue developments in this field of 3D printer technology with vigour in view of the huge possible benefits that could accrue.

(Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the position of the Centre for Air Power Studies CAPS)

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[i] Rajiv Dandotiya, Yuan Fuqing and Uday Kumar, "Optimal maintenance decision for line reparable units (LRU) for an aircraft system", http://pure.ltu.se/portal/files/3293970/LRU_Optmization_paper_Final.pdf, accessed on 09 Jan 2014.
[ii] Ibid

[iii] "3D Printing", http://www.livescience.com/topics/3d-printing/, accessed on 09 Jan 2014.

[iv] "world's first 3D printed metal gun successfully fires 50 bullets", http://www.designboom.com/design/worlds-first-3d-printed-metal-gun-by-solid-concepts-11-08-2013/, accessed on 09 Jan 2014.
[v] Ibid.

[vi] "RAF jets fly with 3D printed parts", http://www.bbc.co.uk/news/uk-25613828, accessed on 09 Jan 2014.

[vii] "Aerospace Maintenance", http://afreserve.com/aerospace-maintenance, accessed on 09 Jan 2014.