Chapter 6

Reinventing Military Innovation

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Introductory Note

Commercial innovation is disciplined by the invisible hand of the market—innovate too little and lose market share, spend too much to innovate and lose profits, innovate the wrong product and fail to sell it. By contrast, peacetime military innovation must be directed "manually" so to speak, because there is neither an invisible hand, nor any objective ways of relating the technological possibilities of the day to strategic priorities, and vice versa. In any case, the armed forces fiercely protect their institutional structures, and therefore filter out or at least try to delay and minimize technological innovations that threaten to change those structures, and the ethos that goes with them. The classic example is the prolonged and continuing resistance of air forces to the substitution of manned with unmanned aircraft, even in applications in which the latter have the advantage.

In the absence of an invisible hand and objective guidelines, innovation priorities and desired equipment configurations are hammered out in a messy free-for-all between rival corporate advocates, politicians safeguarding their own local interests, and the senior officers of different branches and services that are perpetually competing with each other for funding.

Sometimes this free-for-all stimulates innovation, and sometimes it ends up sustaining the status quo against innovation. But in one case, that of the "Joint Strike Fighter (JSF) " or *F-35,* the free-for-all was "gamed" to nullify inter-service competition , and preclude cancellation, even as the costs kept rising and delivery dates kept slipping.

There could be no inter-service competition because the JSF comes in three separate versions, one for each flying service, USAF, USN and USMC.

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Cancellation-proofing was achieved by carefully distributing JSF work to as many Congressional districts as possible.

As a result, the JSF, which was born as the "low end" counterpart to the US Air Force F-22, as in the pairing of the two-engine F-15 with the single-engine F-16, has instead become the most expensive aircraft project in history—and the costs keep rising, even as performance requirements keep being reduced.

That makes the JSF an excellent example of failed innovation, from which much can be learned.

1. Three Quotations

> "The September 7 [2012] Defense Acquisition Board meeting that was supposed to approve a new test and evaluation master plan (TEMP) for the JSF [F-35] [could] not do so. [that] meeting came five months after the release of the 2011 Selected Acquisition Report (SAR) ... which states that the target for finishing [test and evaluation] ... slipped by three years... from April 2016 to a 'threshold' of August 2019..." *Aviation Week and Space Technology* September 7, 2012 p. 35

> "Joint Strike Fighter restructuring continued throughout 2011 and into 2012, adding to cost and schedule. The new program baseline projects total acquisition costs of $395.7 billion [for 2,400 US service aircraft, ie. 164.9 US$ million per a/c, an increase of 42 percent since 2007]." "In 2012, in order to avoid further redesign delays, the U.S. DoD accepted a reduced combat radius for the F-35A and a longer takeoff run for the F-35B." *DOD Actions Needed to Further Enhance Restructuring and Address Affordability Risks*, General Accounting Office AO-12-437, June 14, 2012

> "On schedule and affordability, the JSF program is already a failure. In terms of capabilities and the long-term benefits of commonality, [we do not know]."
> *Aviation Week and Space Technology* October 1, 2012 p. 58

These citations about the largest ever of all US (and multi-national) post-1945 combat aircraft programs reflect both what is present and what is absent in the case of the JSF, and indeed most other major programs that offer only the incremental improvement of classic platforms, instead of new equipment configurations that exploit current technological possibilities.

2. The Compression of Divergent Military Requirements and its Consequences

The entire JSF/F-35 program is characterized by an attempt to obtain " economies of scale" in production by compressing different, even radically different, tactical, operational and even strategic requirements into a single weapon-system platform. Any number of industrial products, automobiles, refrigerators, civilian aircraft and more, achieve high performance at relatively low cost through mass-production, so why not weapon-system platforms too?

In the case of the Joint Strike Fighter or F-35, the different military requirements that had to be compressed included short take-off and vertical landing for the US Marine Corps (and the Italian Navy), aircraft-carrier catapult take-off and arrested landing for the USN (and Royal Navy), and ground attack, stealthy interdiction, reconnaissance, air defense, and agile air combat ("air superiority") for the USAF and other air forces.

What is remarkable about this extreme instance of compression is that it would have been quite enough to cause endless problems even if it has been confined to the USAF requirements alone, because of major incompatibilities between ground-attack weapon loads and interdiction fuel tankage that cannot be carried internally with stealth, between interdiction range/payloads with agility, and between the great multiplicity of tasks and the single human pilot.

As it is, adding the US Navy's catapult and arrestor-gear requirement, while not incompatible in itself, does result in more structural weight than would otherwise have been the case (say no to that, and out goes that part of the supposed "economies of scale"), in direct conflict with the US Marine Corps' vertical-landing requirement with its intense weight sensitivity.

Indeed it is the USMC requirement that has continued to bedevil the entire program, after having distorted the basic design right from the start. In 2004, in a major structural change, internal volumes were reduced to save 2,700 pounds, critical only for the USMC version, because of the power requirements of controlled vertical landings. But that weight and volume reduction could not be achieved without a cascade of sub-system redesign efforts, which added greatly to total costs and further delayed the program. How the wholly disproportionate cost of accommodating the vertical landing requirement came as a surprise to the initiators of the JSF program, is indeed a mystery.

To be sure, economies of scale are very important—when they can actually be obtained. But in the case of the JSF and other weapon-system platforms, the compression of military requirements also has other consequences that increase unit costs disproportionately, thereby finally diminishing procurement numbers and precluding the scale that was the aim in the first place.

To begin with, the increased *system* complexity caused by divergent performance requirements does not impose merely proportional costs: it must instead generate *dis*proportionate costs, as would be the case with any other piece of equipment that must satisfy multiple sets of dynamically opposed requirements. How much would a very efficient manufacturer such as Toyota for example, charge for a car that offers 3 seconds zero to 100 km acceleration, a 350 km/h top speed, 16 seats, room for lots of luggage, all possible ancillaries and accessories, and a range of, say 2,000 kilometers?

But to focus on system complexity alone as a cost driver—a very familiar theme in critiques of procurement policies—would grossly understate the problem, because when different military requirements are compressed, it is not a highly cohesive organization such as Toyota that do the compressing, but rather different armed services with necessarily different priorities. While there are formal decision-making processes involved, by way of Boards, Committees, Inter-Agency meetings and such, the compression of different military requirements typically requires an endless sequence of discussions between the representatives of the different institutions involved. And in military organizations, as in other "total" institutions, internal cohesion outranks external collaboration, so that these discussions are conducted by representatives who are usually under great internal pressure to be fiercely protective of the specific interests of their own institutions.

That is why the salient characteristic of compressed-requirements programs is the succession of decision delays that stretches their duration inordinately, as the effort is made at each remove to find agreement. The JSF contract was awarded to Lockheed Martin in October 2001 (five years after the prototype contract was awarded on 16 November 1996) but there is as yet no firm date for the initial operational capability of any of the three versions. Worse still, under current plans—assuming no further delays—even in 2021, twenty years from the contract start, deliveries will be so few that US air forces will still have to rely mostly on F-15s, F-16s and F-18s of ancient design.

Delivery delays result in lost capabilities in the interim (a very long interim in this case) and are often organizationally disruptive, but their most definitive consequence is the increase in true, i.e., interest-included DCF program costs. Given that the first F-35 moneys were expended in 2001 (if not 1996), the program already carries a great deal of accumulated capital costs even before reaching its initial operational capability.

In addition of course, decision-making by endless discussion between peers will routinely resolve compression disagreements by accepting even more complexity, on top of the initial complexity imposed by the attempt to combine divergent missions in a single platform. If one military service or branch wants to add a bell on the thing and another insists on a whistle, you can be sure that it will have both a bell and a whistle.

The overall effect of these syndromes is the most salient of all characteristics of these compressed weapon programs: inordinately high unit costs, which depress feasible acquisition numbers, which further increase unit costs, which… The process may or may not finally result in a "death spiral," whereby the weapon system is cancelled on its way to an acquisition quantity of 1 (one). But even when cancellation is avoided, production numbers will tend to be much too small to obtain significant economies of scale. In the auto industry, assembly plants that produce 200,000 compatible models per year are more or less the minimum size for efficient production. In the passenger airliner industry, even wide-bodies must be produced at rates of 120 per year for production to be efficient. By contrast, the latest estimate I have seen is that fewer than 300 *F-35s* will be delivered through 2021—the total order numbers in excess of 2,400 stretching to 2040 or beyond are scarcely meaningful. (The *A-400M* Airbus transport whose design compresses strategic and short take-off tactical lift requirements via exceptional complexity, has a grand total of 174 orders after the cancellations caused by cost increases and inordinate delays.)

Whatever such numbers mean, they cannot be sufficient to generate significant economies of scale in production, given processes closer to artisanship than manufacturing.

Thus in conclusion we find that divergent military requirements are compressed to obtain economies of scale, which are then in practice denied by the inevitable cost consequences of that very same process of compression.

3. The Weakening of Competition and the Extinction of Competitors

Civilian innovation is driven by market competition, hence it is continuous. Managers need not be innovative to innovate; all they need do—and must do—is to copy competitors who do innovate. Enterprises that will not innovate nor copy others' innovations do not survive in trades in which antiquity is not itself the prime value (as, e.g., my favorite *Japan Sword Co., Ltd.* of Toranomon).

In wartime, military innovation is likewise driven by competition, though only in the tactical and operational spheres involved (no naval competition in Afghanistan e.g.).

In proportion to its intensity, war propels organizational, operational, tactical and even sometimes strategic innovations, as well as the emergence of new weapon concepts (e.g., armed flying machines in WWI, and the fission bomb in WWII), or at least the emergence of new platform configurations (e.g., jet fighters by 1944, the aircraft carrier by 1918, combat tanks by 1916).

Military leaders need not be innovative to innovate in wartime. All they need do is to copy or otherwise react effectively to enemies who do innovate; if they do neither, they rarely escape defeat.

In peacetime by contrast, military innovation is rare (perhaps the most famous and certainly the largest exception, the nuclear-powered submarine, is also the best example of the near-impossibility of true military innovation in peacetime, given the persistence of the US Navy's consensus in favor of 1,200 psi steam boiler systems and against gas turbines, as well as Hyman Rickover's crazy idea of nuclear propulsion). Military institutions must be especially conservative to perpetuate all-important values of service and sacrifice, but there is no need to berate military conservatism, as any institution that can resist change will do so.

The absence of any true organizational, tactical, operational or technological innovation does not mean the absence of change. When it comes to equipment, exogenous technological progress—and the lobbying of equipment sellers—ensure that the lack of innovation does not stop the processes of "research," development, test, evaluation and new production.

In the absence of new ideas that inspire new equipment configurations, or new technological processes, there is still a steady effort to incrementally upgrade *unchanged platform or other configuration constraints*, to produce ever-more elaborate, sometimes larger/heavier, or otherwise moreincrementally capable, and *much* more expensive equipment.

Disproportionate cost growth with its producibility consequences, is the *inevitable* consequence of trying to extract more performance within the same design and /or technological parameters. The US Navy's beloved 1,200 psi steam boiler systems were predictably twice as volume/weight efficient as their 600 psi predecessors, but they did not cost twice as much—their true cost must have been four, eight or n-times as much because chronic leaks continued even after boiler systems were entirely replaced. (Drastically less complex, altogether more maintainable gas turbines would not be installed on US Navy ships till 1975, even though they had proved their reliability in RN and even USCG service long before.)

What incremental improvement within unchanged configuration or technological constraints cannot yield is any large ("disruptive") result—it produces better typewriters, not personal computers—yet it can still absorb R&D resources in vast amounts, leaving little or nothing for true innovation. Thus, for example, even in 2012, UAVs are still not yet integrated into the standard ground formations of the major armies, even though the Israeli army successfully employed a mechanized division with organic UAVs as far back as the 1982 fight with the Syrian army. In the aftermath, in spite of the totally obvious cost-effectiveness of small observation UAVs to look at the other side of the hill, there was no immediate or even sluggish move to acquire them—evidently because *all* available R&D funds were needed to continue to marginally improve existing battle tanks, artillery and such other well-established weapon configurations. In wartime, the Israeli innovation would have been copied with desperate urgency; in peacetime, it was simply ignored.

(Organizational immobility can be even more restrictive. For example, cyberwar is now obviously with us, and equally obviously, it calls for radically different recruiting, training, discipline and operating practices, of which there is no sign. Yet military institutions that fail to make the adjustments needed in order to attract, train and deploy effective cyberwarriors—beginning with appropriate grooming standards—will most certainly be outmaneuvered by those who do field their hacker regiments and battalions.)

Given this fundamental problem of peacetime non-responsiveness to opportunities for true innovation, which precludes the dynamically competitive creativity found in leading-edge civilian endeavors, the adoption of single, *very* multi-purpose weapon systems configurations such as the JSF is especially damaging, because it precludes even mere benchmarking competition within unchanged configuration or technological parameters, other than with foreign systems—a thing very useful indeed for the runner-up, e.g. China, but not for the category leader. Having adopted the JSF, having given a sole-source contract to Lockheed-Martin, the US Government automatically sidelined every other US contractor potentially capable of designing and developing fighter-class aircraft. The USAF flies the *A-10* developed by Fairchild Republic, but that company is no more, its design team long extinct; and the *F-15*, developed by McDonnell Douglas which was absorbed by Boeing, but that notoriously non-innovative company (it was late even in re-engining the 737) has not had a government-funded fighter program since the 1996 grant of US$ 750 million, and allows only scant internal funding for *F-15* upgrading efforts; the USAF flies the *F-16* but its developer General Dynamics has long since been absorbed into Lockheed; the USN and USMC fly the *F-18*, originally developed by Northrop as the *YF-17* and elaborated by McDonnell Douglas, but the former has no fighter design team, nor even a funded bomber team; the USN and USMC still fly the *EA-6B* developed by Grumman as the *A-6* but that design team is also extinct.

The adoption of the JSF concept of the would-be all-purpose tactical aircraft thus excluded not only the continuation of in-category competition except from abroad, but even the very existence of valid competitors ready to replace that aircraft with their own of the same generation. That in turn makes the JSF "too big to fail" even as it is plainly failing. Under a pathetic headline, "Could the JSF Problem be Fixed with Competition?" (October 1, 2012, p.58), the cited AW&ST editorial suggested the "bold plan" of competing for the purchase of the next 300 fighters between the *F-35* and the *F-15, F-16* and *F-18;* each of the latter can be equipped with the latest AESA radars but even so, these are aircraft that in fundamental ways remain constrained by the aviation technology of 1970 or thereabouts, of forty odd years ago.

If the USMC had been allowed to acquire its desired *Harrier* STOVL successor, the USAF its own *F-22* counterpart light fighter, and the Navy its desired F-18 successor, there would now be at least three fighter-class aircraft to choose from, still only a second-best to truly innovative airpower (surely mostly unmanned) but far better than a single, failing program.

4. The Absence of Operational Realism or Strategic Relevance

The inordinate acquisition delays that are the inevitable consequence of compressing divergent militaryrequirements make any sort of up-to-date realism in defining each of those requirements quite unlikely. By the time major weapon systems procured in this manner reach their initial operational capability, the world will have turned many times, often altering military circumstances strategically as well as tactically.

A most recent example of strategic change with direct equipment implications is the now famous "pivot" turn in US strategy that has replaced predominantly Middle East (and earlier European) air war scenarios in which five hundred nautical miles count as an abundant combat radius for a tactical aircraft, with Pacific scenarios which call for altogether longer ranges—it was so even in 1941.

The resulting increase in the relative value of longer-range aircraft (the best "fighter" might be the *B-2s* with v. long-range air-to-air missiles) could not have been anticipated when the JSF specifications were negotiated between the USAF, USN and USMC, and that is fair enough. But very long gestation periods make it hard to accommodate even the ordinary evolution of sub-systems, radars most notably.

As for tactical and operational realism, these days there is plenty of very recent combat experience to guide the design of body and vehicle armor, small arms, mortars or IED-detectors, but not for the design of combat aircraft. While there has been a great deal of bombing, mostly against targets entirely unprotected by air defenses, there has been no significant air combat anywhere in the world since the June 1982 fighting between Israel and Syria (unless one treats as significant the January 1989 destruction of two Libyan *MiG-23s* by two U.S. Navy *F-14s)*, even whose youngest protagonists are now retired or near enough.

That fighting, moreover, featured one air force that was utterly outmatched in every aspect of capability mostly providing hapless targets, and another that was (and is) very idiosyncratic in everything important, from pilot selection prior to age 18 and accelerated training practices, to the operational integration of RPVs even in 1982. Not much can be learned in 2012 from the thirty-year old experiences of a highly eccentric force.

Instead of the combat experiences and resulting feed-back loops that guided the initial design and subsequent modifications of combat aircraft from 1911 to 1982, with not too long-lived interruptions, there are now only imagined combat scenarios, and records of past experiences that may contain timeless strategic lessons, but which are increasingly irrelevant for design purposes. For one thing, weapon agility can now replace and not merely complement platform agility, sharply demoting what was once the key design parameter for air-combat purposes. With even greater implications, the indispensability of human pilots has been diminishing for years in a trend that continues still. That the JSF program plainly does not reflect either transformation is the reason why it cannot be considered up-to-date, let alone innovative.

5. Platform-fixation(*"platformitis"*)—the Greatest Obstacle to Macro-innovation

The maximally intense military competition of two world wars transformed warfare between 1914 and 1945, giving birth among many other things to canonical weapon-system platforms that have endured ever since. In spite of all the diverse forms of scientific and technological advancement since 1945, in the absence of the revolutionary transformations that only prolonged all-out war can generate, we remain to a large extent (submarines are the exception) with the platforms of sixty years ago and more: the jet- propelled monoplane fighter and fighter-bomber, still recognizably in the configuration of the *Messerschmitt 262* that was operational by 1944; the heavily armored Main Battle Tank armed with a high-velocity, long-barreled gun in a rotating turret, still recognizably in the configuration of the *Panzerkampfwagen VI Sd.Kfz 182* ("King Tiger") of 1944; and the large-deck aircraft carrier with below-deck hangar space and catapults to launch aircraft, still recognizably in the configuration of 1945, or 1955 if an angled deck is the criterion.

Each platform configuration has persisted essentially unchanged, in spite of the advent of increasingly lethal platform-killers in the form of different classes of missiles, and in spite of all sorts of other disruptive changes, because each has become the characterizing weapon system of an entire military service. That guarantees its priority for funding, while excluding the serious consideration of other platform configurations, or more broadly alternative ways of generating combat power.

There are few limits on the propensity of armed services to expend R&D resources on the incremental improvement of their institutionallypreferred platforms, in spite of the disproportionate cost of extracting more performance from unchanged configurations and technological constraints, and in spite of their specific disabilities.

For jet fighters such as the F-35, an important disability is the sheer difficulty of squeezing today's communications, sensor, computational and guidance sub-systems into the nooks and crannies of a small aircraft (a particular current problem is the difficulty of incorporating the cooling sub-system of the ASEA radars, to allow their offensive use). For the army's battle tanks, it is their vulnerability to today's great abundance and variety of anti-tank weapons, ranging from guided missiles and unguided rockets to several kinds of mines. For aircraft carriers, the disability is the vulnerability of flight operations to amply disruptive if not destructive attack by long-range missiles, including ballistic missiles with remotely-guided, maneuvering warheads.

But none of the above disabilities and vulnerabilities have sufficed to wean away the separate armed services from their preferred platforms, to seek macro-innovation via new configurations (such as UAVs, transport-based versatile combat aircraft, etc.), or new forms of combat, starting with cyber warfare.

6. The Remedy: the Reallocation of RDT & E Resources to Defense-wide Purposes.

There have been many attempts to improve RDT&E processes by adding more oversight provisions, to avoid outright debacles such as the US Navy's *A-20*, a stealthy, carrier-based light bomber that was to be the *A-6's* successor, the US Army's *Comanche* reconnaissance/ attack helicopter, and many others such, each a case of relentless cost growth till cancellation.

There is no doubt that ambitious developmental efforts—and in the armed services they are all very ambitious—can easily become open-ended quests for perfection or near enough, incurring costs too phenomenal even for the Pentagon, let alone less wealthy patrons, to develop equipment itself much too costly to be produced at all.

Hence provisions for periodic reviews, for the automatic reappraisal of programs that exceed certain cost-growth percentages, and other such arrangements can certainly be useful.

But as in most other developmental endeavors, very often, if not always, more can be gained by replacing higher probability micro-innovation with lower probability macro-innovation, than with any number of measures to improve the processes of micro-innovation or their oversight.

That in turn leads to a clear-cut conclusion: because the separate armed services are fixated on the incremental improvement of their preferred platforms, the only remedy is to re-allocate RDT&E funds from the separate services to defense-wide decision-makers. They are far more likely to explore promising forms of macro-innovation to obtain new capabilities[2], instead of expending vast resources to incrementally improve existing capabilities at disproportionate cost. Sensor, computational and communication technologies are advancing at a much faster rate than the material and propulsion technologies that characterize platforms. That is why it can seriously be suggested in 2012 that 30 and even 40-year old F-15/F-16/F-18 aerial platforms should be competed against the JSF, while armored-vehicle and naval-surface platforms have evolved even less perhaps, as opposed to the electronics of their sensors, weapons and command mechanisms.

There is no guarantee that the broader perspective of defense-wide decision-makers can outweigh their thinner expertise, as compared to the platform and weapon-system specialists of the separate services. Indeed, efforts would have to be made to overcome the potential imbalance in expertise by recruiting specialized advisors for decision-makers, or to fulfill that role themselves. But the relative advantage of defense-wide RDT&E resource allocation is both more

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[2] Instead of squeezing new kinds of sensors and weapons into the nooks and crannies of classic platforms, they could become the starting point of new platform configurations designed around them; and these can be altogether more efficient if especially demanding qualities such as acceleration and agility are provided either in the platform or in its weapons, rather than in both.

certain and probably much greater in comparison with the *inter*-service allocation of RDT&E resources, to produce compromised systems such as the JSF. They are truly the worst possible option, offering neither the possibility of macro-innovation, nor the in-depth expertise of the single services.