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sit vis vobiscum

## **Systems Engineer *Essentials*:** **5. *SE Principles in Practice!***

*Holism ✓ Synthesis ✓ Organicism ✓*  
*Systems Approach ✓*

**F**ast forward reverse to the 1950s UK. The term ‘systems engineering’ was not yet in vogue. The Cold War was, however, warming. And the Soviet Union were, supposedly, developing “*atomic standoff weapons*”—air-launched medium-range missiles that could be carried by a Soviet bomber and launched when the aircraft was still some distance off the UK coast.

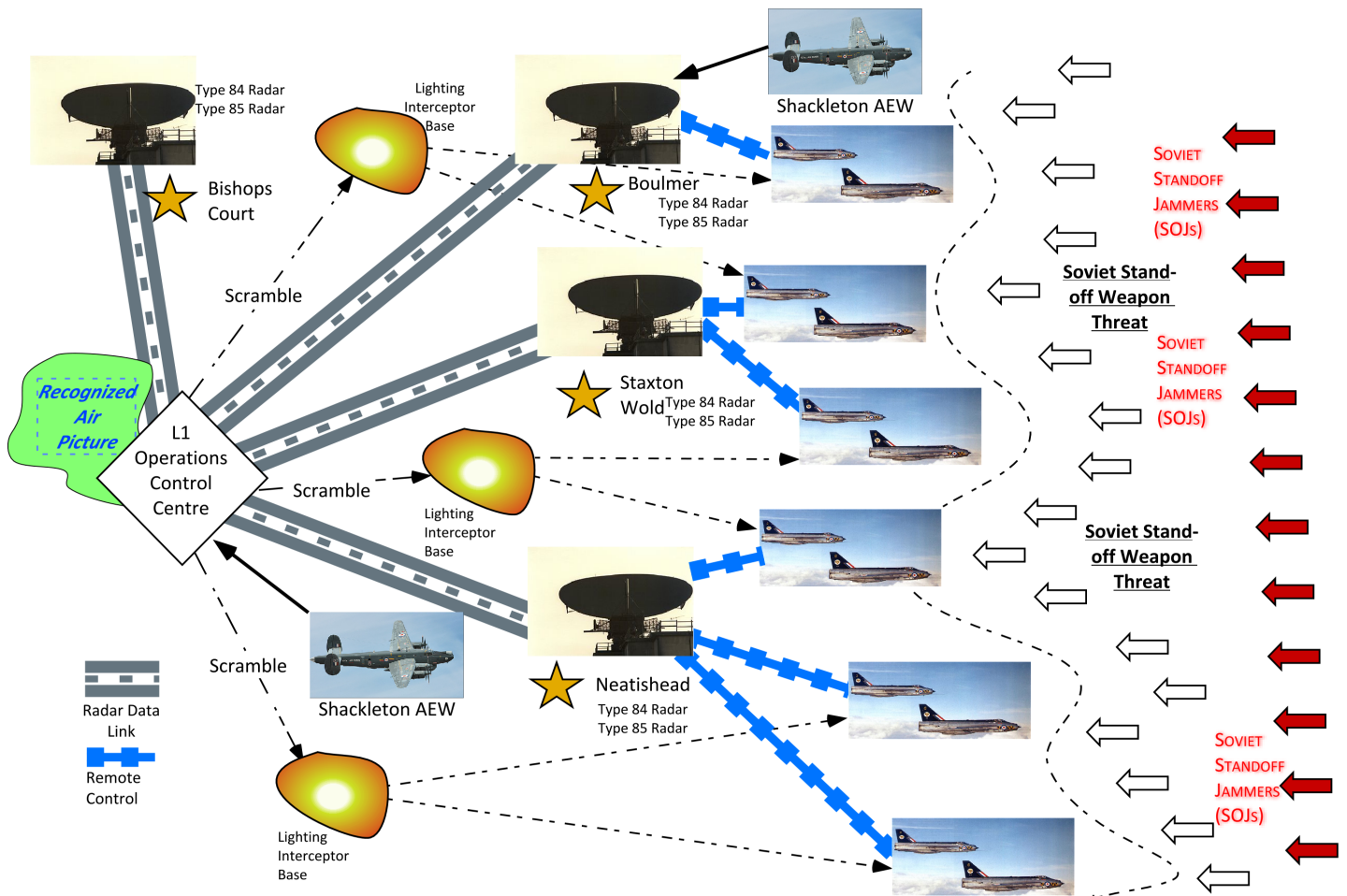
Intelligence sources indicated that as many as 100 such standoff weapons could be launched simultaneously, from different altitudes, against the UK. And that would be—*an existential threat*. Was it real? Was the Intel sound? Could the UK take the chance? So, the *Total Weapon System Concept* was founded in urgent necessity.

**A**nd *Project Linesman* was conceived. Today? Some might call it a major *System of Systems*...? *But—would they be right...?*

Post WWII UK had a number of centres of defence science excellence, including the Royal Aircraft Establishment Farnborough and Royal Radar Establishment Malvern. Their *scientists* and were tasked with finding some way to counter the Soviet Threat. But how? Operations Analysis (OA) had been developed and proven during WWII. OA was essential from the outset. There were many questions to address w.r.t. the alleged Soviet Threat:—

- How could the UK detect the little-known Threat in sufficient time to mount some kind of defence? The innovative *Type 85 3-D* radar, importantly-able to determine target *height* as well as *plan position*, would be conceived, designed and introduced to help resolve this issue...
- The Soviet standoff weapons were too small and fast to intercept using contemporary anti-aircraft artillery (AAA), surface-to-air missiles (SAM) or short range air-to-air missiles (AAM). UK would need, inevitably, to intercept the Soviet aircraft *before* they could *launch* their standoffs—*after launch would be too late*...
- If the Soviets could launch their standoff weapons at, say, 100nm from our coast, then we would need to deploy our interceptors correspondingly earlier.
  - So, we were going to need *Airborne Early Warning* (AEW); airborne aircraft with long range radars that, unlike ground radars, can “see over the horizon.” Shackleton AEW aircraft from Coastal Command would fit the bill.
  - Vitally, we were going to need *an interceptor that could fly out at phenomenal speeds, faster than anything in the contemporary RAF...and were going to need at least one of these non-existent interceptors for each and every standoff weapon—so, at least 100.*

## Total Weapon System Design Schematic—*LINESMAN*



*The Threat is shown on the right approaching from the East. Everything to the left of the wavy line, and facing the threat, is an integral part of only one UK-wide system—Linesman. A singular, dedicated, Total Weapon System...*

- To compound the issue, Intel indicated that the Soviet Threat aircraft with their standoff weapons would be accompanied by *standoff jammers*, to render our radars and wireless communications inoperable, or at best operable only at short ranges.

One of many results from the original OA was that we needed an interceptor that could travel at very high speed, up to intercept-altitudes of c.90,000 feet, that could be directed on to its target by a ground controller despite enemy jamming. And so was born the concept of the

**Lightning** interceptor, a Mach 2+ high altitude fighter with infrared (IR) heat-seeking, ‘*snap-up*,’ air-to-air missiles.

**W**e had the concept. We did not have the aircraft. Happily, English Electric had an experimental aircraft that had the potential to fit the bill— the P1A— but needing copious *changes, additions and alterations* (all *analogue, no digital*) to make it an integral part of **Linesman**:

- An advanced interceptor radar with counter jamming capability, the **Ferranti AI23B**, was fitted into a nose cone in the aircraft’s engine air intake.
- Facilities were installed allowing the **Lightning** to be **remotely controlled** via exceedingly(!) high-power ground-to-air **UHF datalink** on to a target, even through heavy **jamming**.
- A **pilot attack sight** (PAS) was fitted that could show the pilot where ground control believed the target to be, relative to the **Lightning**, plus an intercept profile generated by the **AI23B** which the pilot could follow, with the innovative **Automatic Flight Control System** (AFCS) to perform the “perfect” interception “butcher’s hook” profile, prior to IR missile launch— the early missiles could ‘see’ the soviet aircraft jet engines only from their rear....

**A** key outstanding issue was known as the *Agincourt Problem*. At the battle of Agincourt, on St Crispin’s Day, 1415AD, the French crossbows could fire bolts much further than the English longbows could fire arrows. The French bowmen were using their range advantage to target the English knights. Perhaps the English bowmen, who could not reach the French knights, could fire instead at the incoming French bolts, and protect English knights that way? However, an insoluble problem emerged: how to get each English bowmen to fire at a different incoming bolt...there was no way of allocating targets, so bowmen all tended to fire at the same incoming bolt, leaving other bolts untouched.

**L***inesman* overcame the Agincourt Problem by feeding all of the target information from all of the radars into one central point, the L1 Building. Where they formed a singular *Recognized Air Picture* (RAP). Individual targets from the RAP were allocated to individual *Lightnings*, whose pilots were already sitting in-aircraft, on their respective runways, on QRA—quick reaction alert. Target Allocation problem solved...*No more Agincourt...*

**T**he *Total Weapon Systems Concept* was *holistic synthesis*—classic *systems engineering*. Conducted by a team of *scientists*<sup>1</sup>, not engineers. And it is interesting to note that the main thrusts of the work, initially at least, were:—

- Problem exploration and scoping;
- Multiple, competing concept formulation;
- Operations Analysis of, and comparative evaluations between, the differing conceptual solution systems, resulting in...
- A concept of operations (*CONOPS*), showing the optimum way to go about neutralizing the Threat together with the necessary *emergent properties* of each of the **command centres, sensors, communications, and weapon systems** that would go to makeup the whole.
- *Total System Design*, resulting in...

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<sup>1</sup> *Which set the scene thereafter for Systems Engineering in the UK and much of Europe: Systems Engineering was a unique, systems-scientific discipline—applied systems science—pursued by so-called Systems Houses, which would contract out any engineering required. Later, the US would lump SE and Engineering together in major defense engineering organizations. Thereby reinforcing the misconception that systems engineering was a branch of engineering, in the defense domain...*

- ...Creative, innovative designs, additions, alterations and enhancements for each and every major part of the ***Total Weapon System***, as they became integral parts of the single system that would become ***Linesman***. And the human element—operators, aircrew, engineers and technicians—was ***central***, and incorporated into the concept and functional design, not added as some afterthought... After all, humans perform functions at least as well, if not better, than their technology...
- No customer's specification. No stakeholders. No need...

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**T**he ***Total Weapon System Concept*** of the 1950s and 60s was a remarkable effort by a war-weakened nation in response to an existential threat. It was holistic design, in the true sense of that much-banded, little understood concept:

- *Holistic*: characterized by the belief that the parts of something are intimately interconnected and *explicable only by reference to the whole*.

So, the *whole* was designed as *one entity*. Which resulted in:

**A.** The *parts* (radars, interceptors, control centers, etc.) containing active functioning elements which *made sense only in the context of the whole*. (I.e., '*organismic*')

Looked at alternatively, this meant that:—

**B.** The parts on their own appeared to have superfluous features, i.e., not directly relevant to their individual operational functions. (E.g. the Lightning had residual *data link*,

*programed zoom, and Rocket Assisted Takeoff (RAT) features, not required for conventional Air Defence interceptions.)*

**A**nd, this would seem to be an inevitable feature of any whole, as one system—that there are lateral, interactive, complementary functional links between the parts, that bind those parts into a single, functioning whole...

This would, then, seem to be a necessary feature of a System of Systems, viz., that the whole should be a system (a complex, organized whole) as well as the parts. The implications being that the parts must evidence mutual functional interactions and complementations (*i.e. organismic*). Else the whole is a collection of loosely- or un- related parts (*i.e. mechanistic*), so NOT a system.

**L***inesman*, as the first, significant *Total Weapon System Concept* Project, evidently observed the Systems Engineering Principles:—

- Holism
- Synthesis
- Organicism

But, what about *the Systems Approach*? The *Systems Approach* was, and is, a problem-solving approach. And it's fair to say that the *Linesman* scientists were presented with a *humungous* problem at the outset. That was a given.

*The Systems Approach* also dictates that the solution system be conceived and designed “as active in its operating environment.” It turns out that conceiving and designing weapon systems cannot be achieved otherwise than *in the presumed future combat situation*, against some presumed opponent. It is the nature of the task.

The same appears to be broadly true for *Space*, as well as *Military Systems*. Which observe the *Systems Approach*, willy-nilly.

There is, however, one aspect of the *Systems Approach* that remains unsatisfied. It is the objective of the *Systems Approach* to:

*“satisfy human needs in seeking value truths by matching the properties of wanted systems, and their parts, to perform harmoniously with their full environments, over their entire life cycles.”*

*(Arthur D Hall, MetaSystems Methodology).*

**Linesman** was never tested in anger. But even had it been proved a success, it would not have “performed harmoniously with its full (conflict) environment.” Why not? Because it was the Nature of the Cold War, that the environment was ever-changing, with new existential threats and counters appearing one after the other.

Indeed, the Cold War can be seen in retrospect as a series of successive, mounting threats and counters from each side—none ever being realized in action. Until, with President Reagan’s *Strategic Defense Initiative*,<sup>2</sup> the US “called the Soviet Bluff,” and the USSR chose to take up *Glasnost & Perestroika*.

For the time being...

*Don Del*

*April 2024*

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<sup>2</sup> “**Strategic Defense**” was oxymoronic. *Strategic* implied *Offense*—against the USSR’s MIRVs at their point of launch, while still on Soviet soil... So, taking *Defense of the US homeland right into the Enemy Camp!*