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The Origins of Effects-Based Operations

By PHILLIP S. MEILINGER

Effects-based operations are defined by U.S. Joint Forces Command as “a set of actions planned, executed, and assessed with a systems perspective that considers the effects needed to achieve policy aims via the integrated application of various instruments of power.” The success of any military action is calculated in terms of furthering political objectives.

Airmen have always aspired to conduct effects-based operations, although they did not use that term. During most of World War II, the analytical, cognitive, and intelligence tools needed to determine the effectiveness of air operations were lacking on the strategic level. As a consequence, airmen began doing what they could by resolving a torrent of tactical and technical problems. They counted things, substituting quantification for evaluation. In addition, they assumed that enemies were a mirror image of themselves. Today there are more efficient ways of evaluating effects-based operations, yet there is still a search for a methodology to apply them.

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Under Allied bombs,
1944.

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Lieutenant Colonel Edgar Gorrell of the Army Air Service wrote the first American concept paper regarding strategic bombing while serving in France during World War I. It was strikingly similar to the work of air theorists during World War II. More importantly, Gorrell touched on the precepts of effects-based operations. He noted the stalemate on the Western Front and the toll inflicted on the Allies by German artillery. But the millions of enemy shells that rained down were made at only a few factories. If they were eliminated, production would cease. In other words, if the desired effect was silencing enemy guns, attacking German ammunition plants would have

the same effect as destroying artillery tubes. The same was true of other critical war industries.

Gorrell argued that there were a few indispensable German economic targets without which the war could not be fought. Though vague about targets, he identified four industrial regions.¹ Those who followed him in the next two decades did little better. Billy Mitchell wrote simply that air forces could strike “manufacturing and food centers, railways, bridges, canals, and harbors.”²

A Metaphor of Air War

The doctrine with which the United States went into World War II largely offered lists of standard targets. Army Field Manual 1-5, *Employment of Aviation of the Army*, stated “important objectives may be found in the vital centers in the

all targets are not created equal

enemy’s line of communication and important establishments in the economic system of the hostile country.” Besides focusing on enemy forces, this publication suggested targets such as rail lines, bridges, tunnels, power plants, oil refineries, and similar objectives. But more imaginative ideas were germinating elsewhere.

Two events occurred at the Air Corps Tactical School, one minor and out of proportion and the other more significant. The instructors-cum-pilots at the school found their planes grounded.

Springs in the propeller assembly had failed and replacements were back ordered. The parts were made in Pittsburgh, but the factory was closed because of floods. This seemed significant. If one wanted to achieve air superiority, perhaps it was only necessary to destroy one factory rather than every enemy airfield or aircraft.

Although this scenario may appear too simplistic as a basis for military doctrine, there was more to it. America and much of the world experienced the Great Depression during the 1930s. Businesses and financial institutions failed. Major powers were brought to their knees without a shot being fired. Economies are delicate systems. If the desired effect is rendering an enemy incapable of waging war, strategic bombardment may devastate its economy. Victory may follow. But infrastructures are huge and one might not be able to attack every factory, power station, rail line, bridge, and steel plant. What targets are the most important or vulnerable? The example of propeller springs provides a clue because it implies there are key nodes within an economic system on which it depends. All targets are not created equal. The springs became a metaphor for a way of looking at air warfare—the search for the strategic bottleneck.

Prior to World War II it was difficult for airmen to obtain information on the economies of potential enemies. There were no resources for such intelligence, and American isolationism made such an endeavor inappropriate. Instead, the officers at the Air Corps Tactical School looked at the industrial northeast and gathered data on power grids, steel mills, oil refineries, and transportation systems. Even more significantly, they tried to discover how systems worked. In short, air leaders had an inherent belief in the importance of effects-based operations and a rudimentary understanding of how systems should be measured and evaluated. They did not, however, have the analytical tools to conduct that measurement and evaluation.

When Europe went to war in September 1939, an air war plans division was established in the War Department to devise target sets in the event the United States entered the war. The initial effort was small and hesitant, but businessmen, engineers, and other members of the private sector were soon contacted. In some cases they studied factories in Europe that American banks helped finance or construction companies helped build. In others, experts simply explained how U.S. systems operated, assuming that those in Germany were similar. This was largely a hit-or-miss approach, often depending on businessmen. There was an obvious risk of what can be called the blueprint availability syndrome, in which the type of intelligence gathered shapes one’s view of

"A Bridge Too Far."



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a system. If planners had ample data on the German ball bearing industry, they might put too much emphasis on its contribution to the war effort while missing other target systems.

Other bodies were formed to study the German economy. One was a group of American business executives, lawyers, and economists who were known as the Committee of Operations Analysts and another was the Enemy Objectives Unit in London, which advised Allied air leaders for the balance of the war.

These groups studied the German economy to determine the most lucrative targets for air attack. Unfortunately, they lacked the data to make reasoned judgments. As the official history of Army Air Forces put it:

... there existed in almost every instance a serious shortage of reliable information, and the resulting lacunae had to be bridged by intelligent guesswork and

the clever use of analogies. In dealing with this mass of inexactitudes and approximations the social scientist finds himself in a position of no special advantage over the military strategist or any intelligent layman; and an elaborate methodology may even, by virtue of a considerable but unavoidably misdirected momentum, lead the investigator far afield.³

To overcome these limitations, analysts initially looked for information in enemy newspapers and periodicals as well as from business and industrial experts as noted above. Such poor sources led to the misconception that the German economy was hard pressed and thus was susceptible to attack with devastating results. For most of the war Germany actually had remarkable slack. Because Allied economies had been put on a wartime footing, it was assumed that the enemy had as well. But in fact, it had not. For example, automobile manufacturing, the largest industrial sector of the German economy in 1930s, barely ran at half capacity.

Measures of Merit

Economic analysts became increasingly capable of understanding effects-based operations. This was due partly to their criteria and methodologies for gathering information on the German economy, accessing it, and then looking at targets. They examined factors such as total production of a given commodity, minimum operational requirements, surplus capacity, ability to substitute other materials, time needed to repair facilities, damage sustained, and the ratio between pool and production. The last factor identified

essentially, measures of merit linked objectives to targets

commodities that could be stockpiled for an appreciable time. Thus oil was initially considered a large pool, so its destruction would have little immediate effect. Similarly, U-boat production was slow, with most submarines on active service or in port. Thus hitting the factories that manufactured them would not be decisive. On the other hand, aircraft were expended quickly in combat and there was no pool on which to draw. Destroying the plants that built them would have a rapid effect.

Once planners determined key nodes, industries, and commodities, they had to answer two questions. Were air strikes destroying the targets? If they did, were they having the predicted ripple effect throughout the war machine?

Estimating if bombers were actually destroying their targets was difficult. Data on accuracy was hard to obtain, and the extent of destruction when bombs hit was not obvious. Like today, assessing bomb damage was as much art as science. Post-strike aerial photography, for example, indicated that attacks on ball bearing factories in Schweinfurt in 1943 caused extensive damage. After the war, however, it was learned that many bombs detonated on top of buildings, collapsing the roofs. The results looked impressive from the air, but only 5 percent of the machines on the floor were damaged and most were quickly repaired.

Beyond this level of analysis, intelligence and planning agencies had to confront the subject of indirect effects, which required measures of merit. Although the term was popularized earlier by the total quality movement, the concept was understood in World War II. Essentially, measures of merit linked objectives to targets. But the specific type of evidence analysts should examine to determine if targeting strategies were achieving their political goals remained a thorny issue.

The Tedder Plan

At Casablanca in January 1943, Franklin Roosevelt and Winston Churchill agreed that the objective of the combined bomber offensive was “the progressive destruction and dislocation of the German military, industrial, and economic system, and the undermining of the morale of the German people to a point where their capacity for armed resistance is fatally weakened.”⁴

This was a highly and perhaps deliberately ambiguous directive that allowed readers to take away from it what they wished. Air Chief Marshal Arthur Harris of Bomber Command saw the order to undermine enemy morale as a vindication of night area-bombing. To Lieutenant General Carl Spaatz, senior American air commander in Europe, the operative phrase was “the progressive destruction” of economic and industrial infrastructure—the mission of daylight precision bombing. General Dwight Eisenhower, who became Supreme Allied Commander for Overlord, was focused on the need to invade. In his view, the main function of bombers was supporting the assault on the French coast to ensure that “armed resistance was fatally weakened.”

By early 1944, planning for the invasion was in full swing, and the question of a combined bomber offensive to complement landings arose. American analysts revised estimates of German oil supplies and decided reserves were not as large as originally thought. If true, refineries should become the top priority for Allied bombers. If the lifeblood of the economy stopped pumping, the entire war machine would collapse—one of the stated goals at the Casablanca conference.

Other air planners focused on the German rail network. Troops, supplies, equipment, and raw materials moved primarily by train. If railway lines were cut, the German war machine would come to a halt together with the entire economy. The debate tended to break along national lines, with Americans backing the oil plan and most British, notably Air Chief Marshal Arthur Tedder, deputy supreme Allied commander, advocating the rail plan.

The argument ended in March 1944 when Eisenhower opted for the rail plan. The deciding factor was time. For Ike, measures of merit required air superiority to isolate the beachhead area from enemy reinforcements. He wanted that capability for the invasion and not at some point in the following weeks. Although he agreed with Spaatz that the collapse of the oil supply would be catastrophic for the German war machine, that could not be expected until the autumn, too late for Normandy. The rail plan won the day because it promised a solution to immediate problems—the effects desired by Eisenhower.



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U.S. Air Force

Planning air operations.

Yet there was even disagreement on the rail plan. If the desired effect was halting traffic, what parts of that system should be targeted? Possibilities included rail cars, locomotives, repair facilities, round houses, marshalling yards, and railway bridges.

Solly Zuckerman, a primatologist in the University of Oxford before the war, worked for Tedder in the Mediterranean theater. He studied railroad bridges versus marshalling yards in Sicily and on the Italian mainland in 1943 and concluded that the latter were more desirable targets simply because they were larger. Given the inaccuracy of Allied bombers, bridges were small and took disproportionate tonnages to knock out. Because the marshalling yards were expansive, bombers were more likely to hit something of value, thus bombing these yards was more efficient.⁵ Tedder agreed and directed his planners accordingly.

When Tedder and Zuckerman left the theater, Lieutenant General Ira Eaker, USA, the new commander, reviewed the decision. He concluded

that Zuckerman was mistaken. By using more data on air operations in his sample, Eaker discovered that bridges were not as difficult to hit as previously thought, especially with medium rather than heavy bombers operating at high altitudes. In addition, marshalling yards could often be repaired within days while it generally took several weeks to repair a bridge.

These findings became important as planners grappled with preparations for Overlord. If the desired effect was isolating the beachhead by preventing German reinforcements from reaching the area—Eisenhower's goal—how best could airpower achieve it? Tedder and Zuckerman, now in London, dusted off their earlier analysis and again pushed for marshalling yards. Spaatz and his planners, led by Charles Kindleberger and Walt Rostow of the Enemy Objectives Unit, disagreed. Using extensive analysis from the Mediterranean, they argued for a bridge campaign.

Like the broader question of oil versus rail, the more specific issue of railways generated bitter debate for the next four decades. In the event, air leaders resolved the dilemma in their usual manner by bombing both marshalling yards and bridges. There was enough Allied airpower by mid-1944 to follow several targeting strategies. By

D-Day, Ninth Air Force alone, with more than 4,000 aircraft, was larger than the entire combat strength of the *Luftwaffe*.

It would be unwise, however, to pass over this question too quickly. Determining whether Zuckerman or the Enemy Objectives Unit was correct had more than academic interest. Planners will not always have infinite air assets at their disposal. As seen over the past decade, those assets may be limited by political considerations and not a lack of airframes. In such cases, air planners should know how to achieve the greatest effect to fulfill policy objectives.

Picking the Right Objective

Zuckerman and Rostow published memoirs after the war, attacking each other with gusto. Their supporters and detractors entered the fray, but one of the more insightful accounts came from Henry Lytton, an economist on the War Production Board and the Economic Warfare Board. It is not just his conclusions on the relative importance of bridges versus marshalling yards that are of interest, but his insights into the methodology and assumptions of the respective protagonists.⁶

Lytton considered what were being used as measures of merit. Zuckerman was interested in the density of bomb patterns within designated target areas. Marshalling yards were large; thus a much higher percentage of bombs fell in that area than when the target was a small rail bridge. Kindleberger and Rostow were more concerned with effects. If only one bomb out of a thousand hit a bridge and dropped it, that was preferable to having all the bombs landing within the confines of a marshalling yard and leaving even one rail line intact. The enemy assessment was the same. The German officer in charge of the Italian transport system stated that strikes on marshalling yards destroyed goods and rolling stock but not tracks, which in any event could be quickly repaired.

In short, the objective was stopping trains, not putting a certain percentage of bombs within a grid. Choosing the wrong measures of merit will defeat effects-based operations. In early 1945, Tedder received unexpected support. The Allies had broken the Enigma codes and produced what was called Ultra intelligence. However, the German rail system, which had been using teletype or telephone to transmit reports, began using Enigma in January 1945. Signals intelligence personnel largely ignored messages on rail traffic,

but when Enigma was adopted, they paid more attention. By February, a study of the traffic revealed the role coal played in the economy, virtually powering all industries and providing 90 percent of energy supplies. Coal moved almost exclusively by train once the rivers and canals were mined by Bomber Command. When the rail plan took effect, coal movement slowed down. The implication was clear: to deliver a death blow to German industrial production and military capabilities, the Allies had to stop the flow of coal. That meant stopping the trains.

In essence Tedder had been right all along, only for the wrong reasons. Neither he nor his planners identified coal as the commodity that made the enemy function. His plea for a campaign against German railways (as opposed to those in France, which had been the centerpiece of pre-invasion bombing) emphasized disruption of the flow of reinforcements and supplies. The goal of an expanded rail campaign was to “rapidly produce a state of chaos which would vitally affect not only the immediate battle on the West Wall, but also the whole German war effort.”⁷ Since coal was never mentioned, Tedder was not interested in studying intelligence related to its shipment.

But when examined almost by accident in February 1945, the significance of coal quickly became apparent. The evidence had been there all along; it merely required someone to establish coal as the crucial link and identify the desired effect with an appropriate measure of merit—halting its movement by rail. Once this key relationship, desired effect, and metric were articulated, the bombing campaign could be focused on achievement.

A further consideration highlights the sometimes serendipitous nature of war. The railway system did not adopt the Enigma code to secure its reports at such a high level of classification, but because bombing had knocked out the teletype network as well as most telephone lines and even the postal service. Otherwise Enigma probably would not have been used, and the Allies would never have been curious enough to look into the movement of coal by train.

Technological War

Although targeting was a key factor in effects-based operations in World War II, questions remain. Was there a particular node the heavy bombers should have concentrated on? Contenders for this magic bullet were oil, coal, rail lines, electricity, and ball bearings. Were these targets really key or *panacea targets*, the derisive term of Arthur Harris? In his view, the German economy was so large, complex, and redundant that only its wholesale destruction would bring the country to its knees.

the wrong measures of merit will defeat effects-based operations



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Raid on Germany.

The German perspective on the Allied air offensive is instructive. Albert Speer, Minister of Armaments and War Production, later wrote:

I shall never forget the date May 12 [1944]. . . . On that day the technological war was decided. Until then we had managed to produce approximately as many weapons as the armed forces needed in spite of their considerable losses. But with the attack of nine hundred and thirty-five daylight bombers of the American Eighth Air Force upon several fuel plants in central and eastern Germany a new era in air war began. It meant the end of German armaments production.⁸

On the other hand, Speer later wrote Hitler about the bombing of rail lines on the Ruhr:

We are on the verge of the most serious coal production crisis since the beginning of the war. . . . For more than six weeks now, in the matter of transport the Ruhr has become more and more cut off from the areas it supplies. . . . It is clear from Germany's overall economic structure that in the long run the loss of the industrial area of Rhineland-Westphalia would be a mortal blow to the German economy and to the conduct of the war.⁹

Further confusing matters, when Speer was interrogated following the war, he stated that the crucial targets that should have been attacked more vigorously were chemicals, ball bearings, and electrical power, implying that they were more important than oil or coal. It would seem that not only were the Allies uncertain about the

economy of Germany, but the head of its armaments production was confused.

While effects-based operations were at the root of what airpower was intended to achieve, planners went to war without precedent for determining objectives, targets, and measures of merit for strategic bombing. At the same time they had almost no experience in gathering intelligence for such campaigns. These processes, both requiring substantial resources and skill, had to be created anew. Although mistakes were made, one must not underestimate the task of collecting economic intelligence and then planning and conducting an economic warfare air campaign.

Analytical tools have improved dramatically. Unfortunately, questions over effects-based operations persist: the adequacy of intelligence, the lack of cultural sensitivity, the risk of studying inputs rather than outputs, and the need for models to account for cognitive, cultural, political, and social factors. These are serious questions, and their solutions are not obvious.

Airmen have always desired to conduct successful effects-based operations. For much of the first century of airpower that aspiration was out of reach because of technological limitations on aircraft and weapons as well as inadequate intelligence and analytical tools. Now those tools and technology are beginning to catch up. **JFQ**

NOTES

¹ Maurer Maurer, *The U.S. Air Service in World War I*, volume 2 (Washington: Office of Air Force History, 1978), pp. 141–57, reprints the Gorrell memorandum.

² William L. Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power, Economic and Military* (New York: Putnam's, 1925), pp. 126–27.

³ Wesley Frank Craven and James Lea Cate, *The Army Air Forces in World War II*, volume 2 (Chicago: University of Chicago Press, 1948–58), p. 369.

⁴ *Ibid.*, p. 305.

⁵ Solly Zuckerman, *From Apes to Warlords* (New York: Harper and Row, 1978), pp. 209–10, 220–23.

⁶ Henry D. Lytton, "Bombing Policy in the Rome and Pre-Normandy Invasion Aerial Campaigns of World War II: Bridge-Bombing Strategy Vindicated—and Railway Bombing Strategy Invalidated," *Military Affairs*, vol. 47, no. 2 (April 1983), pp. 53–58. Lytton's title pretty much says it all.

⁷ Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany, 1939–1945*, volume 4 (London: Her Majesty's Stationery Office, 1961), pp. 290–92, contains Tedder's "Note on Air Policy to be Adapted with a View to Rapid Defeat of Germany," dated October 25, 1944.

⁸ Albert Speer, *Inside the Third Reich* (New York: Macmillan, 1970), p. 346.

⁹ Webster and Frankland, *The Strategic Air Offensive*, pp. 349–56, contains a letter from Speer to Hitler dated November 11, 1944.