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Rise of the War Machines: The Birth of Precision Bombing in World War II by Raymond P. O'Mara.

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Review by William D. O'Neil, Falls Church, VA (w.d.oneil@pobox.com).

US Air Force colonel Raymond O'Mara (ret.) wrote his MIT doctoral thesis on bomber aircraft seen as syntheses of man, machine, and doctrine that culminated in the European air war of 1942–45.[1] *Rise of the War Machines* grew out of that dissertation.

The World War II Army Air Forces (AAF) constructed its first fully realized system of strategic bombing around the Boeing B-17 four-engined heavy bomber and, to some extent, the contemporary B-24. Though the B-17 flew in many theaters, it is strongly associated with the England-based 8th Air Force, which bombed targets in Germany and German-occupied Europe. O'Mara clarifies the thesis of his book in its introduction:

> History has shown that, in order to understand the impact of a particular technology on how humans accomplish tasks, it is necessary to understand the roles of both humans and machines in performing those tasks—what does each human or machine do when performing the task and how do the human and machine interact? … To achieve this understanding, we need to understand how and why automation came to be used in air warfare as well as how it informs the mutual relationship between humans, machines, and the doctrine that guides their creation and use. (4–5).

The doctrine here of high-altitude daylight precision bombing (HADPB) emerging in the 1930s is taken as a given.

The B-17 normally flew with four officers and six enlisted men. O'Mara concentrates on the officers, pilots, copilots, navigators, and bombardiers who controlled the aircraft's offensive capabilities. Each in turn is examined closely in relation to the systems he used to carry out his function as well as the doctrine shaping the systems and the role of personnel. The author also describes the training that officers underwent to hone their complex skills. He stresses the tight union of human and machine in executing HADPB doctrine. The commanding figure, literally, was the pilot, who by World War II had evolved into the *aircraft commander* of a large and complex plane with a crew of skilled specialists.

The pilot was expected to manage manually a number of systems and features and carry out very stringent mission demands. The author describes how 8th Air Force doctrine came to require large formations assembled in "wings" of as many as fifty-four aircraft each. The bombers based at some four dozen airdromes scattered north of London had to climb steeply, often through thick English overcast, to join their formation in clear air.

Throughout the mission, which might last over eight hours, the pilot had to play his assigned role in the formation, assisted by the copilot. If his bomber was damaged by fire from fighter planes or antiaircraft guns, he struggled to get it home or save the crew if the plane was lost.

1. "The Socio-Technical Construction of Precision Bombing: A Study of Shared Control and Cognition by Humans, Machines, and Doctrine during World War II" (Diss: MIT, 2011).

The pilot's chief technical aid was the autopilot, a gyroscopic device able to operate the B-17's controls as programmed by the pilot. As O'Mara describes, the demands of the HADBP doctrine and the European air war ultimately gave birth to modern aircraft control technology. The intrusion of automation into the realm of pilot skills caused tensions ultimately resolved by the pilots's eventual mastery of the complex autopilot system.

Until the eve of war, the AAF had insisted that qualified pilots should be responsible for all the functions involved in controlling the aircraft's flight. As bombing missions had stretched to hundreds of miles, often in conditions of poor visibility, navigation had become a full-time task requiring an additional pilot to perform it. As bombing itself grew ever more complex, it was realized that a dedicated crewman would be needed for that function too. As President Roosevelt demanded a huge expansion of US air forces, AAF leadership developed distinct non-pilot officer specialties to facilitate navigation and bombing functions of aircraft.

The intricate operations performed by the new navigator and bombardier officers required them to work closely with elaborate systems and mechanisms according to a fixed program. Precision and refinement in execution was everything, together with resourcefulness in surmounting any disturbances to the program.

Though O'Mara is less detailed on specific mechanisms, he does discuss the famed Norden bombsight's development and superiority to other bombsights, though he makes no international comparisons. To execute the HADBP doctrine in its intended form required that the bombardier see the target clearly for at least the last fifty seconds of a bomb run—and well enough to identify it for several minutes before that. Unfortunately, the weather over northwestern Europe seldom provided the essential visibility. But, by late 1943, the AAF had slowly begun equipping its bombers with radar and other special electronic equipment to aid in hitting targets under cloud cover.

In his last chapter, O'Mara discusses the overall model of relations among doctrine, humans, and machines in HADBP and successor bombing doctrines. Projecting the model forward in time, he briefly examines the F-111 (active 1967–96) and F-117A (1983–2008), both of which he sees as successors of the B-17.

As a historical study, *Rise of the War Machines* has significant drawbacks, most notably its omission of radar and other advanced bombing and navigation systems. That said, the book is a valuable and welcome sociotechnical analysis of complex weapons systems. Students of World War II and especially strategic bombing will appreciate its many new insights into the subject.