

Down the final crane bay at Trenton, N.J., come the nearly completed Avenger torpedo-bombers to receive paint, propellers, radio equipment and the other finishing touches that will make them first-class fighting machines. Folding wings are tested, too.

From Autos to Aircraft:

General Motors' WW II Conversion

By Robert L. Caleo

Automobile companies were asked to manufacture 75 percent of the engines required for combat aircraft during WW II, but only two of their operations took on the job of building complete airplanes. Ford Motor Company produced B-24 bombers for the Army in a new, custom-built plant at Willow Run, Mich., while General Motors (GM) converted existing facilities in New Jersey, New York and Maryland into carrier-plane sources for the Navy.

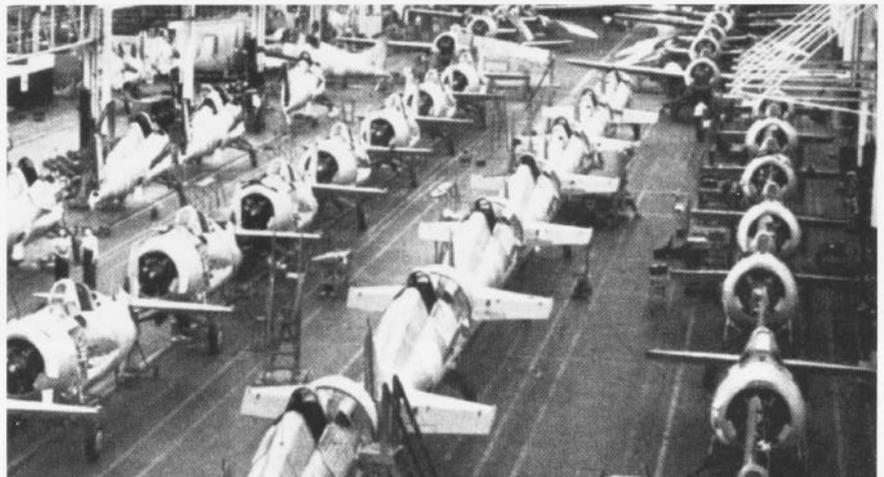
Though GM's effort has received less historical attention than Ford's, it

was more successful in terms of at least one quality criterion. Its facilities consistently met the Navy's delivery schedules; Ford's production, on the other hand, lagged for a time.

GM's real competition, though, was half the world away at the Zero fighter

plants of Mitsubishi Heavy Industries and Nakajima Aircraft Company, headquartered in Tokyo, Japan. Just six weeks after Pearl Harbor, the Navy enlisted GM to make both fighters and torpedo-bombers for its carriers, as well as some for the British. Many of

Wildcats in various stages of completion move through the vast, high-vaulted final assembly bay at Linden, N.J.—illustrating the amount of activity going on every day in a wartime aircraft plant.



Workers at Bloomfield, N.J., demonstrate how air under pressure is shot through each tube to check for obstructions or imperfections. Many hundreds of these tubes go into each plane.

To the Japanese, the Zero represented more than a weapon. It was almost a state of mind. The pilots who flew the single-seat fighters likened them to skyborne samurai swords, and as Zero designer Jiro Horikoshi divulged after the war, Japan's military strategists originally believed "one Zero would be the equal of from two to five enemy fighter planes, depending on the type."

Little more than a month after Pearl Harbor, waves of Zeros were already spearheading attacks on New Guinea and the Solomon Islands—gateways to Australia. Before that, they had supported invasions of Guam, the Philippines, Malaya, the Dutch East Indies and Wake Island. Operating from island bases and aircraft carriers, they seemed to be everywhere in sizable numbers, escorting bombers and troop ships, strafing airfields and anti-aircraft batteries and generally overwhelming the U.S. and British planes confronting them.

Desperate to gain air-sea supremacy in the Pacific and to counter the German U-boat menace in the Atlantic, the Navy arranged an extraordinary liaison between giant General Motors

the planes were destined for the Pacific and inevitable encounters with Japan's small but deadly Zeros.

The fast-climbing, highly maneuverable enemy fighters were initially a surprise

to most Americans. Yet, when they appeared at Pearl Harbor they were already battle tested, having earlier outperformed China's American-, British- and Russian-built warplanes.

rsion to Wildcats and Avengers

and the much smaller, suddenly over-committed carrier-plane developer, Grumman Aircraft Engineering Corporation. The duo's mission, with GM in the unlikely role of second contractor, was to lift America's naval aircraft production to the levels demanded by a two-ocean war.

Curiously, the Navy's paired-production strategy paralleled one the Japanese had already adopted. Since 1939 Nakajima, then the leading aircraft manufacturer in Japan, had been mass producing the basic Zero, while Mitsubishi, the fighter's developer, concentrated on improved models. In the U.S. scheme, General Motors—not an aircraft

The old automobile final assembly line at Linden, N.J., was used temporarily to train workers in aircraft production. Everyone learned something new—inspection, rivet sorting and welding (shown here).



By using this ingenious upper-deck platform at the Tarrytown, N.J., plant, employees on the wing conveyor line are able to quickly put final touches on one of the largest bomber assemblies. The width of the wing requires this unique apparatus.

Senator Harry Truman and his Senate Investigating Committee visited the Trenton and Linden, N.J., plants on 15–16 March 1943; they were impressed with the speed and completeness of the conversion from automobiles to planes.

firm but the world's top auto maker—was contracted to assume production of Grumman *Wildcats* and *Avengers* so that the source company could work on a new, more advanced plane.

The crucial questions for the Navy's Bureau of Aeronautics, the contracting agency, were: Could GM apply the auto industry's celebrated manufacturing skills to plane making, and could that be done fast enough to affect the course of the war, particularly in the Pacific? There seemed to be little doubt about the answers at the leader level.

Donald M. Nelson, the nation's War Production Board chairman, maintained that "when the war started there were not more than three countries, outside of the United States, whose entire industrial war-making potential was greater than that of the American automobile industry."

According to GM chairman Alfred P. Sloan, his corporation's objective

An aircraft's "skin," already fastened, is riveted to the cone-like frame of the rear fuselage by workers at the Baltimore, Md., plant.



was "to transform the world's largest automobile company into the world's largest manufacturer of materials for war" and in doing so to take on "the most complicated and difficult production assignments."

Nowhere was GM expertise challenged more than in the East Coast operation





set up to make the Grumman-designed aircraft. Plants at Linden, Trenton and Bloomfield, N.J.; Tarrytown, N.Y.; and Baltimore, Md., were merged into an ad hoc GM division called Eastern Aircraft. The Navy's contract called for the new unit to produce its first fighters and bombers by the fall of 1942, mean-

ing that it was being asked to convert from autos to aircraft in less than half the time it normally took to develop a new car model.

To get started, Eastern had to first tear down some highly productive assembly and parts lines—ironically, the kinds of facilities that had attracted the Navy. Before the war the Linden plant had been one of the world's most advanced car assembly factories, turning out Buicks, Oldsmobiles and Pontiacs at a peak rate of one per minute. Trenton, a hardware facility, had produced as many as 750,000 door locks, hinges, trim moldings and the like per day.

For the Navy, Linden would switch to assembling *Wildcat* fighters and Trenton to *Avenger* torpedo-bombers. They were supported by a Delco-Remy battery plant at Bloomfield and Fisher Body-Chevrolet factories in Tarrytown and Baltimore. These plants were responsible for subassemblies, such as wings, tails, cockpits and electrical systems.

All of the plants had to undergo procedural and work-force transformations as well as physical ones. Eastern needed to form a new supplier network of more than 3,000 subcontractors to obtain aircraft materials and parts. The division's 9,000 employees required

retraining provided by nearby plane manufacturers, colleges and vocational schools. And, because plane making was still a more manual process than auto making, the work force had to be more than doubled and staffed mainly with unskilled emergency recruits who required basic tools instruction.

Eastern overall could best be characterized as an "apprentice," or learning organization, in 1942. Its general manager, Louis "Cliff" Goad, said as much the following year in an article on the division's conversion written for *Flying Magazine*: "Let me confess at the outset that I am a 'Johnny-Come-Lately' to aircraft production. My entire career has been devoted to problems of automotive manufacture, most of it in the accessory business. In the matter of how to produce spark plugs or batteries, I could speak with some authority. In the complex field of aircraft manufacture, I don't pretend to know all the answers. But for the last year, we have been finding them the hard way—working around the clock, immersed to our necks in machines, techniques, and nomenclature unknown to us 12 months ago."

Goad and staff had come to their new business steeped in the principles and practices of standardized mass production—the process of translating well-documented designs into precisely machined parts that could be rapidly joined into replicated products on mechanized assembly lines. Their reorientation began soon after Eastern Aircraft was formed when they asked Grumman for complete parts lists and engineering data for the *Wildcats* and *Avengers*.

In the automotive process, designers had normally directed material buyers and machine tool makers through fully detailed requisitions and drawings. At aircraft firms, however, extensive use was made of hand tailoring by highly skilled mechanics guided by discussions with engineers and sketches. Purchasing requirements had often been communicated the same way.

As Eastern unhappily learned, many of the specifications it needed were in workers' heads at Grumman's plants at Bethpage, Long Island, N.Y.



Splash! Mary Martin, star of Broadway and Hollywood, christened the 2,500th *Wildcat* in a ceremony for employees.

Supervisors from each of the division's facilities were quickly sent to Grumman to dig for the information. They used every possible research approach, from asking questions, peering over shoulders and taking notes to studying drawings and files, measuring finished parts and photographing components and assemblies. Key specifications were immediately phoned back to Eastern, which gave buyers there a head start in setting up the nationwide supply lines necessary to procure some 10,000 different aircraft parts.

Grumman itself became Eastern's first supplier. Because the Navy insisted, for maintenance reasons, that the two manufacturers produce planes with interchangeable assemblies, it was



It started with a coin and grew to \$5,256 when Linden, N.J., workers, in a spontaneous demonstration, stuck their cash around an Eastern Wildcat for the Navy Relief Fund.

decided that one more step should be taken to guide Eastern. Grumman shipped finished *Wildcats* and *Avengers*, with major parts held together by temporary fasteners, to Linden and Trenton, respectively. The parts could be easily removed for measurement and analysis by tooling machine designers, assembly line planners and other engineers at Eastern.

Unfortunately, this reverse-engineering tactic only illustrated how soft aircraft standards were. Many of the model components did not conform to the specifications on Grumman drawings

examined earlier, and some even differed from ready-made parts that the Long Island company began sending to Linden and Trenton to help Eastern build its first planes.

This snag in its search for basic data marked the lowest point in Eastern's first year of operation, according to the division's official history. Eastern was then in its third month, with only six left for delivery of its initial *Wildcat* and seven left for the *Avenger*. Its production departments were ordered to construct the first few planes in the aircraft industry's job-shop style, while the division's engineers painstakingly developed the data needed to tool up for mass production.

The engineers adopted an idea that aircraft firms had borrowed from shipbuilders. They laid out full-scale outlines of the *Wildcat* and *Avenger* and doggedly, over a period of months, filled them in with drawings of the thousands of parts involved. Each of the parts was drawn to the exact size desired in production; thus, purchasing and tooling standards were finally set and documented.

While solving its start-up problem, Eastern was faced with a more profound dilemma, which Goad described this way: "In the automobile a given design is fixed over a definite and fairly long period. The design of a modern warplane is fluid. It can be changed on a moment's notice—and is. That is probably one point most of us in the automobile industry failed fully to appreciate in the beginning."

Goad's words do not convey the jolt that his engineers felt when they realized a cornerstone of GM practice—freezing designs to maximize output—would not be transferable to their evolving wartime operation. Eastern began receiving Navy requests for changes in both *Wildcats* and *Avengers* while still gearing up for production.

A number of the modifications resulted from growing knowledge about the *Zero*, which in effect became a benchmark for the Grumman-Eastern tandem in the early part of the war. For Eastern this was one more start-up hurdle. It involved making 4,000 engineering revisions beginning with the eleventh *Wildcat* assembled at Linden.

Though the stubby *Wildcat* could rarely match the *Zero* in one-on-one dogfights, it was rugged enough to expose some weaknesses in the enemy

plane. As a marine pilot at Guadalcanal put it, "A Grumman [*Wildcat*] can sometimes take [long-term] fire from a *Zero*, but the *Zero* can't take two seconds' fire from a Grumman."

The explanation came when Navy engineers had an opportunity to evaluate a captured *Zero*. Apparently, to achieve superior speed and maneuverability, Mitsubishi had minimized its fighter's weight—trading off armor plating in crucial areas, such as the cockpit. Further, the *Zero* had not been equipped with self-sealing fuel tanks, which were standard safeguards in the Grumman-designed fighters.

During its first six months of production, the division received orders for over 100 design changes, including adding more guns to the wings of the *Avenger*. To cope with such volatility, Eastern abandoned a core practice of the auto industry. With locked-in car designs and large-volume runs, it had been expedient to use highly specialized machine tools, each doing a single job rapidly and economically. To build ever-changing warplanes, Eastern had to switch to more pliable machines capable of performing, or being converted to, different tasks.

"Over a period of months, Eastern Aircraft was going to violate nearly all of the sacred precepts of mass production philosophy, but of these violations and compromises a new technique of manufacturing was born," the division's history noted. Goad presented further perspective during a press conference held in December 1942 to mark his organization's successful changeover to producing complete combat aircraft—the first such conversion of auto industry facilities in the nation. With GM chairman Sloan at his side, Eastern's general manager began by establishing realistic expectations for his hybrid operation.

"It is safe to say we cannot now and probably never will see during this war mass production of aircraft as we knew it in the automotive industry," he told some 100 journalists in discussing the "constant, even feverish improvements" required in military planes. But, he reassured them, Eastern's production would be high enough to meet the Navy's needs.

Touring the Linden and Trenton plants, the reporters saw some of the reasons for Goad's optimism. Conveyors, monorails and other flow-enhancing mechanization—hallmarks of the auto



The new FM-2, known as the "wilder" Wildcat, made its debut for members of the press in the Linden, N.J., hangar. A huge, realistic paper-and-wooden circus wagon housed the 'cat before it broke loose.

industry—were being put to work in the plane-assembly process. Giving its impressions the next day, the *New York Times* wrote: "The task of change-over has been a colossal one. . . . Of even greater significance than the physical and technical transformation is the success with which the techniques of scheduled flow of material through a plant have been applied to structures like fighters and bombers. . . . Eastern Aircraft is at once a testimony to the cooperation and the 'know-how' of both aircraft and automobile management and a harbinger of even finer performance for war and for postwar industry."

Eastern at that point had exceeded its production target for 1942 by delivering over 20 planes to the Navy—twice the number expected in its start-up year. In its journeyman year, however, the target set by the Navy skyrocketed to four figures. The division was charged, in 1943, with driving its production high enough to relieve Grumman for full-time work on the ultimate *Zero* killer, the new *Hellcat* fighter.

Concurrently, Eastern faced yet another conversion. The Navy needed a smaller, lighter, faster climbing version of the *Wildcat* for its versatile escort carriers—the "baby flattops" comprising shortened flight decks on freighter-size hulls. Escorts were already being used effectively in the Atlantic by both

U.S. and British fleets for convoy protection and air-sea pursuit of German submarines. They were destined to play a vital role in the island-by-island takeback of the Pacific, serving as offshore bases for planes—usually *Wildcats* and *Avengers*—supporting amphibious forces.

Operating from the escorts, the new *Wildcats* would become feared island attackers during the second half of the war, much as the *Zeros* were earlier. The design for the model, called the FM-2, was handed off from Grumman to Eastern early in 1943. By the end of the year, Linden had assembled over 300 FM-2s, plus 1,100 of the earlier *Wildcats*, the last FM-1s produced for the U.S. and British navies.

For Linden, according to Eastern's history, the *Wildcat* changeover was "fully as great as changing from one year's model to the next in automotive manufacture—except that in this case the plant could not shut down to retool." Because of the Navy's escalating demands, there could be no production gap between models. In fact, Linden's output had to keep rising while a seamless transition was made.

Just as the plant had intermingled Buicks, Oldsmobiles and Pontiacs on its prewar assembly line, it built FM-1s and FM-2s simultaneously for part of the war. Gradually, the former were phased out as greater numbers of the

"wilder *Wildcats*"—Eastern's nickname for the peppier FM-2s—were put into the production stream.

As Linden engineered its nonstop cutover, Trenton was teaming with the division's other plants to keep up with soaring orders for the *Avenger*. The three-man torpedo bomber, one of the war's biggest single-engine planes, had fast become the heavy hitter on U.S. carriers after making its debut at Midway. With its 2,000-pound torpedo or equivalent bomb load, it could pound ships, submarines and land facilities.

The *Avengers* could not be readily manufactured under a single Eastern roof. The bombers' dimensions and their complexities, such as built-in bomb bays, motorized gun turrets and folding wings, dictated that they be constructed modularly. Baltimore produced the tail sections, Bloomfield the electrical and hydraulic systems and Tarrytown the cockpits and wings. Finished components were shipped to Trenton, where they were joined to fuselages on a final assembly line.

Two weeks before Christmas 1943, Eastern presented its 1,000th *Avenger* to the Navy, and the following month it assumed sole responsibility for the bomber's production. At a Trenton ceremony, the plant's manager promised that the next 1,000 *Avengers* would be delivered in one-third the time.

The division's progress and confidence were manifestations of its transition from learner to sharer in the wartime aircraft industry. By 1944 all of its plants reflected GM's proficiency at developing coordinated, continuous manufacturing operations.

"The learning process that resulted from the cooperative effort of Grumman and GM was by no means a one-way street," wrote Richard Thruelsen years later in his history of the Long Island company. "Grumman also learned from the GM production experts, particularly in the fields of tooling, automation and production-line dynamics. The lessons were opportune for Grumman, with its vast influx of inexperienced and unskilled workers. . . . The machine and the system had to fill the gap created by a shortage of highly skilled labor."



The Baltimore, Md., final assembly line at shift change. A long line of Avenger tail sections parade through this area day and night. The finished products are whisked away from the end of the line and shipped to Trenton, N.J.

Grumman and Eastern made a total of some 35,000 planes during the war, the bulk of the Navy's carrier aircraft. When their combined volume peaked in 1944, the second contractor's production exceeded the original contractor's. The Navy rated Eastern's product quality as "the equal of the best in the industry." Further, GM's division by then was the highest producer of naval aircraft in the world, surpassing even Nakajima, whose output of *Zeros* and carrier-based bombers was being retarded by severe material shortages.

Eastern was the source of more than three-quarters of the nearly 18,000 *Wildcats* and *Avengers* delivered in the war years. Significantly, it became a top producer in time for the Navy's climactic Pacific offensive, beginning with the invasion of Kwajalein early in 1944 and ending with the occupation of Okinawa—on Japan's doorstep—in mid-1945. Aircraft out of Linden and Trenton supported every major assault and helped turn back the Japanese navy at Leyte Gulf in the Philippines, in the war's last and biggest sea battle.

Meanwhile, the once-exalted *Zero* was headed for oblivion. Late in 1944, south of Leyte, 10 of the Japanese fighters carrying 550-pound bombs crashed down on a group of escort carriers, damaging several and sinking one. This was the first of many planned kamikaze attacks by *Zero* pilots.

Japan's suicide missions were partly the result of the peaking production lines at Eastern, Grumman and other U.S. aircraft companies. As American warplanes improved and proliferated, they took control of the Pacific skies, reducing the *Zero*, with its few remaining experienced pilots, to a desperate role.

The *Zero's* downfall is generally attributed to the Navy's Grumman *Hellcat* and Chance Vought *Corsair* fighters, but the *Wildcats* and *Avengers* must share the credit. *Avengers*, not a direct threat to the Japanese fighters, often undermined them by bombing their island bases as well as their carriers. Future President George Bush, one of the Navy's *Avenger* pilots, was engaged in raids on airstrips and radio facilities

in the Bonin Islands when he was forced to ditch his bomber in September 1944.

The next year, as the war moved closer to Japan, *Avengers* were used in some carrier-plane attacks on Tokyo-area airfields and airplane plants. By that time Nakajima and Mitsubishi operations were being disrupted by regular B-29 poundings, which damaged factories and slowed supply deliveries, compounding the material shortage problem.

In the end, after a considerable head start, Japan's aircraft manufacturers found themselves unable to produce enough reliable *Zeros* or other planes to defend their country against the superior U.S.-produced aircraft. ■

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Photos courtesy of *A History of Eastern Aircraft Division, General Motors Corporation, 1944.*