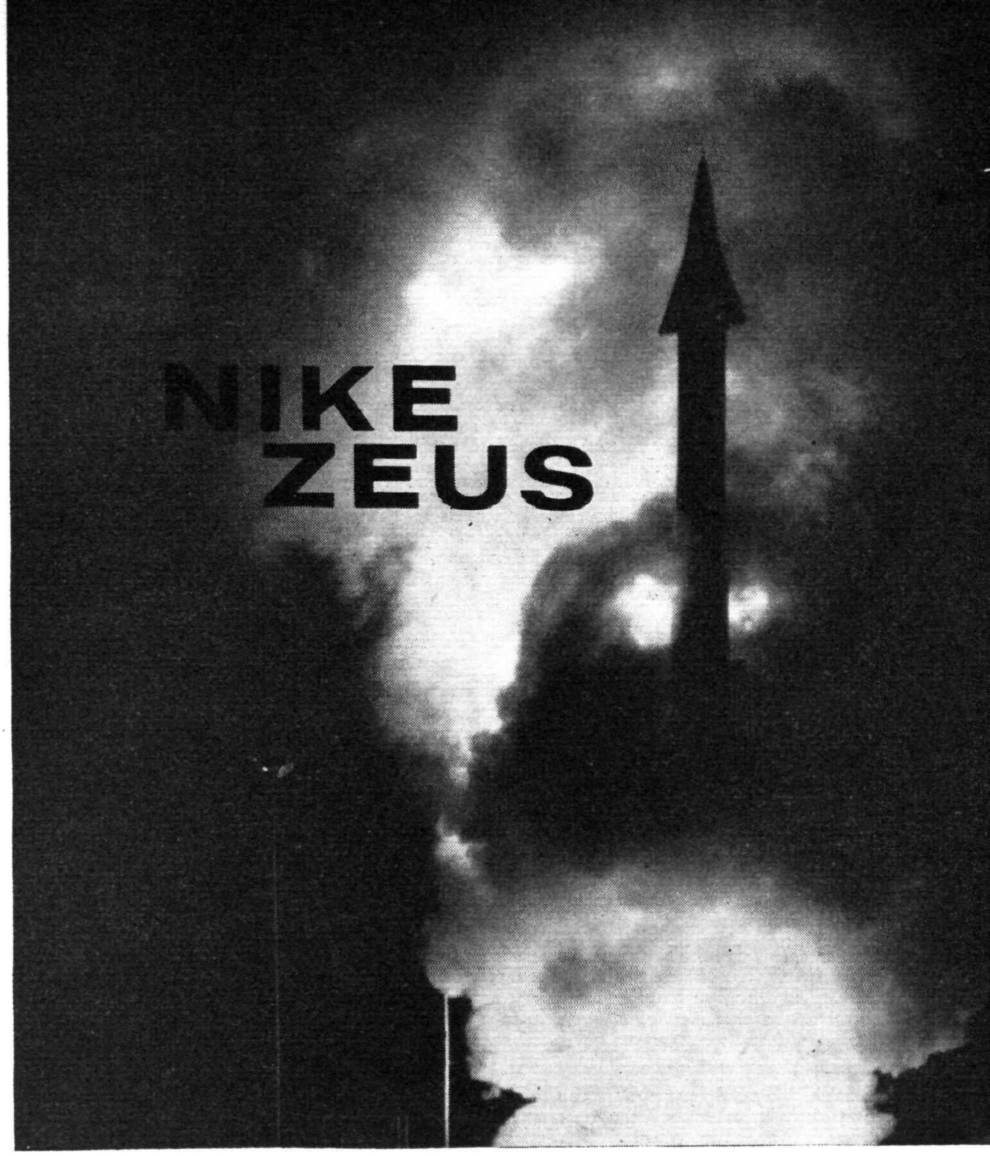
Missiles and Spaceflight



Seventeen years of system growth

BY THE TECHNICAL EDITOR

TWO weeks ago a Nike Zeus missile fired from a coral atoll in the Pacific Ocean successfully intercepted the slender, 16,000 m.p.h. re-entry vehicle of an Atlas ICBM fired from Vandenberg AFB, California, 4,300 miles to the east. If this sort of thing could be done reliably, and at a moment's notice, anywhere in the world it would have a profound effect on the military plans of the United States and Soviet Union. The latter nation has made various claims to have anti-missile defences actually in being; America is defenceless against ICBM attack—apart from her own ICBMs, the latest of which are secure in "hardened" bases—but has demonstrated her ability to acquire a measure of protection with the Zeus test of July 19.

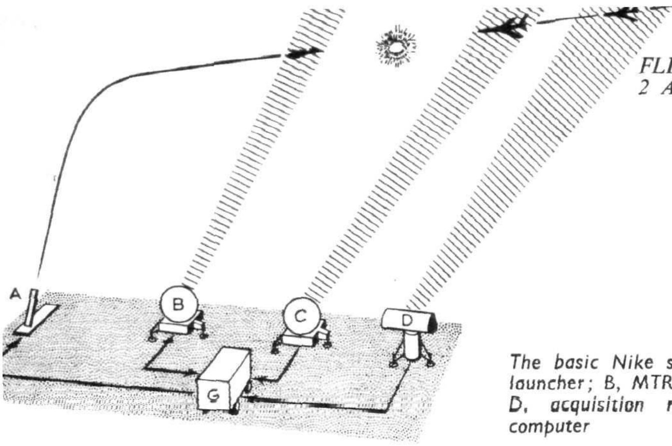
This appears to be an appropriate time at which to review the philosophy and engineering behind Nike Zeus, though to do so in a single article poses a problem, the magnitude of which can be summed up in three sentences. Nike Zeus is not just a missile but a weapon system weighing thousands of tons, occupying approximately 200 acres, and incorporating fundamentally new scientific discoveries and engineering accomplishments. The cost of deploying Zeus operationally would be astronomical, and it is widely felt that there must be a better defence against the ICBM than to try to intercept the descending warhead; but the alternative has yet to be found. Finally, Zeus is the third generation of a family, and for completeness one must begin in the middle of World War 2.

There have been various estimates of the mean number of anti-aircraft shells needed to destroy a single attacking aeroplane, but by 1942 the Germans had reached the conclusion that guided missiles appeared to offer a surer answer. Three years later the US Army studied the German systems carefully when it laid the groundwork for its own Project Nike,* and eventually decided to employ similar radar command guidance. So, for that matter, did the Russians, Swiss and French, while we British went straight to more sophisticated—and more difficult—solutions.

Initially the programme was intended to have an 80 per cent kill probability against a target able to manœuvre at 3g at a speed of 1,500kt at 40,000ft. The missile was called Nike Ajax, and data for it are grouped in an accompanying table. Although the system is quite large and costly, its operation could scarcely be simpler, and the same basic method has been retained right up to the Zeus. Targets are first picked up by an acquisition radar, which feeds a computer to which is coupled a target-track radar (TTR). The TTR locks-on to the target and continuously supplies the computer with range, azimuth and elevation data. At the first possible moment the computer launches a missile, which is thereafter tracked by the missile-track radar (MTR). The computer then simply steers the missile by appropriate MTR instructions in order to bring the TTR and MTR data into coincidence as soon as possible. When this is achieved the computer commands the warhead (there are three in Ajax) to detonate.

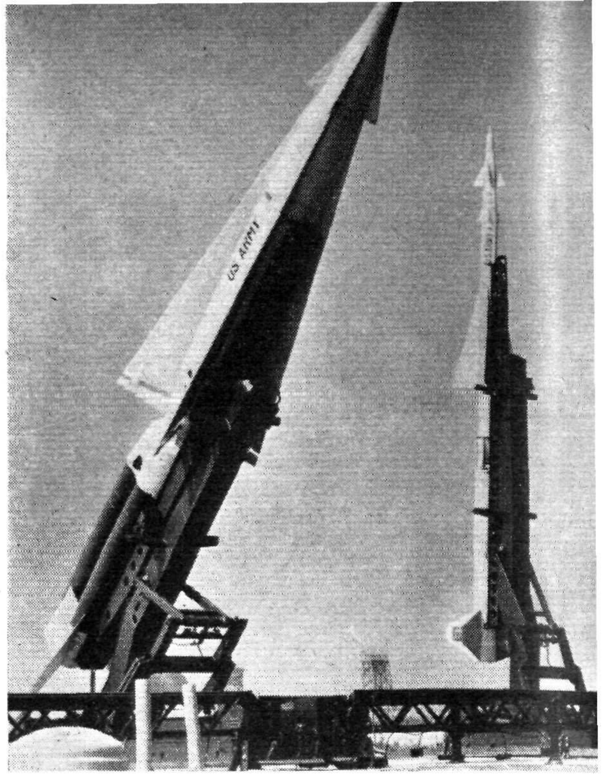
To produce the finished hardware the Army formed a tripartite team comprising Western Electric (prime), Bell Telephone Laboratories (system design) and Douglas Aircraft (missile). These organized a vast network of subcontractors who succeeded in developing the weapon system to the operational stage by 1953. Since that time Ajax has been deployed in hundreds of batteries throughout CONUS (the continental United States), US military installations throughout the world, and 12 or 13 members of NATO or SEATO.

** Named after a lethal Greek goddess and pronounced "Nikey."*



The basic Nike system: A, launcher; B, MTR; C, TTR; D, acquisition radar; G, computer

Missiles and Spaceflight



Nike Hercules (left) and Nike Ajax

A sketch of a typical launch area, and a fuller description of the whole system, appeared in this journal's first annual review of the world's missiles, published on December 7, 1956.

While the Nike system was still being developed it was appreciated that it lent itself admirably to being progressively improved by the introduction of better component parts. This policy was put into effect, and the system reliability and performance of existing Ajax batteries have steadily risen in consequence. Today an Ajax battery can consistently exceed the original system design capability, can operate in 60 m.p.h. winds in dust, sand, rain, snow or salt-laden air, and can sustain a rate of fire of roughly a round a minute until all ready-rounds have been used. Officially an Ajax can "destroy any known operational aircraft."

Nevertheless by 1953 it was clear that the lethality of the system was in many respects limited by the missile itself, and the design of a completely new missile, named Nike Hercules, was put in hand. As the data emphasize, it is larger and heavier than Ajax, yet it was designed to be compatible with the same storage, ready rooms, ground-handling, launcher, and fire-control radars as were already in use with the earlier missile. However, the Hercules has enabled the overall system performance to be extended so greatly that in most instances it has been installed in completely new batteries; 19 of the original Ajax battalions in CONUS were turned over to the National Guard, but these too are fast converting to Hercules.

Specifically, Hercules has greatly increased effectiveness at both very high and low altitudes, can carry a nuclear warhead, and has nearly four times the range of Ajax. A Hercules battery includes a director station, tracking station and acquisition radar, in addition to the TTR, MTR and computer. The majority of units, both in CONUS and elsewhere, are integrated into national or supranational defence systems, but a Hercules battery can function with complete autonomy. If necessary it can operate against surface targets, provided their precise location is known. It is possible to enter the necessary data into the computer in approximately five minutes. The missile is then launched and guided by the MTR towards an aiming point high over the target. At the correct instant the MTR issues a dive command and the nuclear warhead is detonated by a barometric fuse.

Hercules became operational on site in June 1958, and initial production requirements (except for INH conversion kits, discussed presently) were fulfilled by December 1960. More than 80 batteries equipped with Hercules are at instant readiness in CONUS, and probably about 40 in other locations. During 1958 the system was examined to determine whether it could be made mobile, and thus defend a field army, and a mobility kit for the standard launcher and a completely new series of GOER transporter-launchers were evaluated in field trials.

Hercules naturally incorporated many of the lessons learned with Ajax, but it has likewise proved amenable to continual improvement. The ethylene-oxide turbopump for the airborne hydraulics was replaced by a battery-powered system, and the original Ni-Cd battery was changed for one with a solid-state electrolyte. More drastic changes followed, and new ground equipment led to Improved Nike Hercules or INH. This incorporates improvements to the TTR, presentation and tactical controls, plus a further acquisition radar, the HIPAR, capable of detecting any aircraft at extreme range and height despite an intense ECM (electronic countermeasures) environment, and the TRR target-ranging radar which helps the TTR by having many new circuits able to meet sophisticated ECM threats. CONUS Hercules units are steadily being up-graded by kits, some of which do not include HIPAR. Proof of what INH can do were the destruction of a Corporal ballistic missile on June 3, 1960, and the interception of one Hercules by another in August 1960. The latter took place at 32 miles at about 60,000ft with a closing speed in excess of Mach 7.

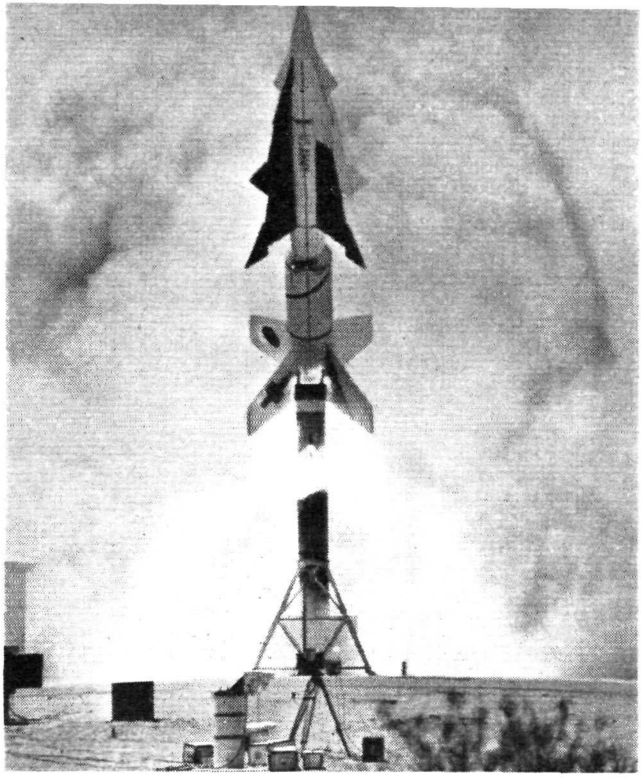
Zeus

During 1956 the Army asked Bell Telephone Laboratories to investigate the feasibility of producing a system which could provide defence against an ICBM. There were two lines of approach: a detailed study of how much could be achieved with any conceivable modification of the INH system then under development; and an uninhibited investigation into all possible methods.

Modification of the existing Nike system committed the scheme to interception of the enemy re-entry vehicle at a realtively late stage in its ballistic trajectory. This is obviously undesirable. The radar cross-section of an ICBM re-entry vehicle is very small, and its characteristic "signature" varies with configuration and size, re-entry velocity and angle of attack and with a number of atmospheric factors, and at this stage of the mission may be obscured by various decoys. The sheer speed of the vehicle means that the entire interception must be accomplished against the clock to such an extent that the survival of a city may depend upon hundredths of a second, with no possibility of success should any part of the defending system malfunction. Finally, the enemy warhead must be either rendered harmless or be detonated high enough for no harm to be done on the ground below.

In spite of these objections, interception of the descending warhead appeared to be the only solution possible within a reasonable time-scale. During 1957 the Army authorized the long-established Nike team to start the design of the Nike Zeus system—the first, and so far only, anti-ICBM system in the West.

Simple calculations show that the enemy warhead must be intercepted more than 100 miles above the country being defended. Plotting the ICBM re-entry backwards at a rate of some five miles per second, the whole process appears to defeat its own ends. The need to detect, identify and plot the trajectory of the target imposes a minimum time which must elapse before the defending Zeus can be fired. There are two main conclusions: the tiny target must be picked up and accurately plotted by radar at distances of the order of 1,000 miles; and the Zeus must rise out of its hole in the ground and reach the point of interception at an *average* speed higher than a mile a second. Eleven-ton Zeus takes off like a bullet; and it leaves behind it a gun consisting of some of the most advanced and most powerful electronics in the world.



Nike Zeus early test configuration

Nike Zeus at White Sands

To understand how the system works it is appropriate to outline a typical interception, which is accomplished in some 170 seconds. First hint of an enemy ICBM attack would probably be picked up by a BMEWS radar, but the Zeus is designed to operate without such help. It has its own acquisition radar, or **ZAR**, and this is the biggest, most expensive and most critical part of the whole system. The acquisition radar of Hercules can detect targets at, say, 200 miles. If the Zeus ZAR can pick up a target at 1,000 miles it must have 25 times as much power—or 125 times, if one considers the radar cross-section of a nosecone to be one-fifth that of a bomber.

ZAR is served by nine 1,500kW generators, some held at instant readiness to come on line in the event of power failure. The big cables lead underground to the ZAR transmitter building, in which are 18 megawatt-range klystrons each weighing 1,100lb and encased in lead shields. Their fantastically powerful signal is ducted up to a triangular array of three aerials. From the feedhorn in the centre of each side the signal escapes on to a parabolic reflector and passes out through one of the 80ft-long windows, which are of laminated-glass honeycomb with an integral copper polarizing grid, and protected by a pneumatic de-icing boot. The vast triangle rotates at 10 r.p.m. to sweep the sky, and since its radiation is considered lethal at under 330ft radius the whole transmitter is surrounded by a 65ft fence at 350 ft. Even the hangar-size building is skinned in a special alloy to prevent the signal from re-entering.

Should an aircraft fly over the **ZDC** (Zeus defence centre), where the ZAR is located, it would return a signal to the ZAR receiver millions of times stronger than that for which the equipment is designed, and this must obviously be allowed for. What the ZAR is looking for is the characteristic signature of its own target, a relatively small and slender body of revolution hurtling along in outer space some 1,000 miles away. Such a target sends back an unmistakable return signal; but one so faint that the ZAR receiver has to magnify it millions of times.

Since return signals may come from a number of targets in any direction, the receiver aerial takes the form of a rotating hemispherical Luneberg lens with a diameter of 80ft (the same as the length of the three transmitter aerials). The hemisphere is made of 34,484 18in cubes of plastic foam ("42 box-car loads"), each impregnated with precisely arranged metal filaments. The outer surface is protected against the weather by a 120ft nylon radome and the whole 2,800,000lb of aerial rests on 36 hydraulically balanced shoes moving around a circular track with a diameter of 30ft and sector tolerance of 0.0005in. The aerial is slaved to the 10 r.p.m. of the transmitter, the angular accuracy being measured in seconds of arc. Any incoming signal is refracted in an optical manner by the millions of metal filaments and focused into receiver horns arranged in groups of about 50 in 3ft-wide banks spaced round the hemisphere at 120°. The signal strength from each bank of horns varies with the position of the target, and after amplification through a 4°K maser circuit provides azimuth, elevation and range data.

Next the system has to decide whether the return signal is really that of an incoming warhead; and it may also have to distinguish between the package of megatons and a surrounding cloud of decoys. It would be easy at this point to be side-tracked into discussing decoys, but the publicly expressed US view is still that the only thing which looks like an ICBM warhead is another ICBM warhead. The US Army and Air Force are co-operating in obtaining actual signatures with both Atlantic and Pacific ICBM firings, and a great deal should be learnt from such steamy-sounding projects as DAMP (downrange anti-missile programme) and PRESS (Pacific range electromagnetic signature study) and the tracking of Atlas and Titan re-entry vehicles equipped with the cleverest possible decoy systems.

(Continued on page 170 after double-page drawing of Nike-Zeus system)

THE ZEUS TEAM

OVERALL cognizance for the Nike Zeus weapon system is held by the Army Rocket and Guided Missile Agency, of the Army Ordnance Missile Command at Huntsville, Alabama. Prime industrial contractor is the Western Electric Co, the manufacturing and supply unit of the Bell Telephone System, who have been producing prototype radar and electronic equipment at three North Carolina locations (Burlington, Greensboro and Winston-Salem) and special transistors at Laureldale, Pa. System design and research is the responsibility of Bell Telephone Laboratories, Whippany, NJ. These organizations are supported by 14 US Government laboratories and facilities and by thousands of subcontractors, of whom the following are most important.

Missile Airframe, motor cases and nozzles, missile-handling and test equipment and delivery of assembled missile, Douglas Aircraft, motor work taking place at Torrance, Cal, and missile assembly at the Charlotte, NC arsenal; finished booster and sustainer and jethead propellant, Thiokol; guidance stable platform, Lear; accelerometers, Minneapolis-Honeywell; hydraulic a.p.u., AiResearch; control hydraulics, Vickers; warhead, Picatinny Arsenal.

ZAR Transmitter, Continental Electronics; aerials, Goodyear Aircraft; dielectric materials, Armstrong Cork and Dow Chemical; receiver aerial drive and hydrodynamic bearing, Westinghouse Electric; reduction gears and azimuth bearings, Western Gear.

TTR Transmitter, Sperry Gyroscope, Surface Armament Division; aerial, Allis-Chalmers, Continental Can (mount) and Narmco; aerial gearing and bearings, Western Gear; aerial drive, Vickers.

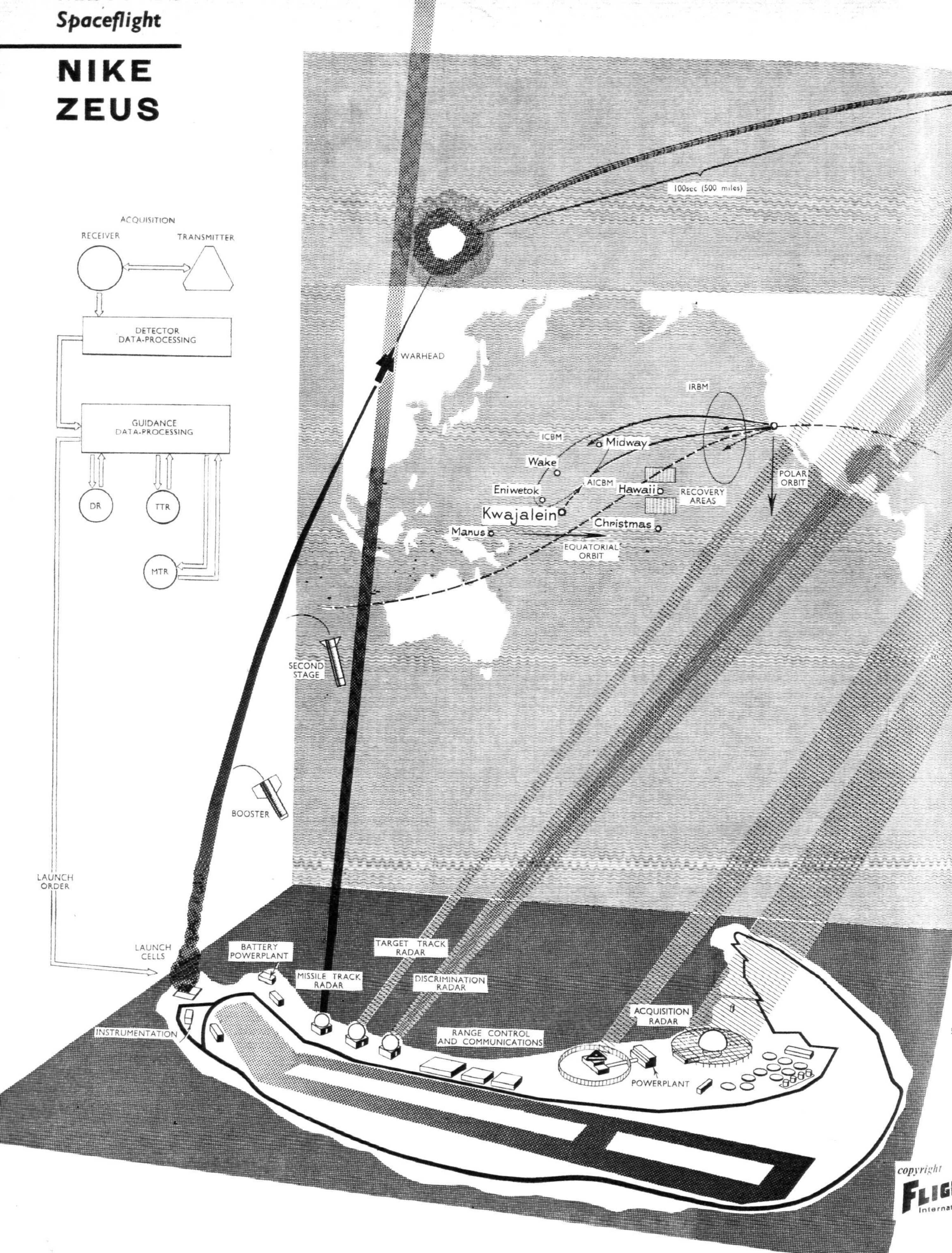
MTR The MTR aerial is by Steel Products Engineering.

DR Basic design, Sperry Gyroscope; discrimination technique studies, Avco-Everett Research Laboratories, Cornell Aeronautical Laboratories and Bell Telephone Laboratories; subcontractors, Goodyear Aircraft, Westinghouse, Telecomputing Corporation and Wheeler Laboratories.

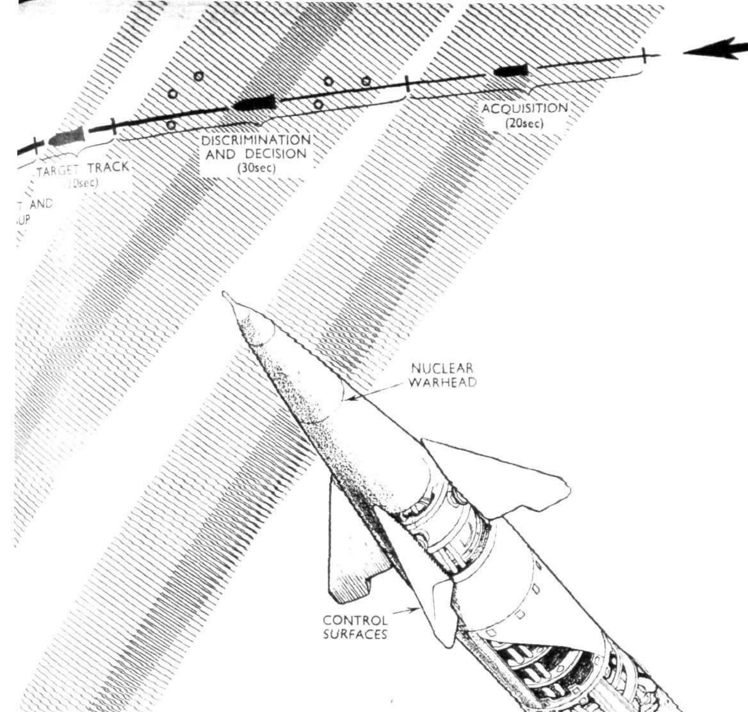
TIC Remington Rand Univac.

Miscellaneous Ground checkout installation, Stromberg-Carlson; tactical displays, Texas Instruments; refrigeration systems, Air Products (for masers) and Arthur D. Little; waveguides, Doehler-Jarvis; megawatt duplexer, Bomac Laboratories; battery packs, Eagle-Picher; rotary joints, ITE Circuit Breaker and FXR; bearings, Kaydon Engineering and Messinger Bearing (radial); RF plumbing, Wheeler Laboratories; technical facilities design, Burns and Roe; design of buildings and utilities, Mobile (Alabama) District of US Army Corps of Engineers; construction of test facilities at Kwajalein, Pacific Construction (Honolulu), Reed and Martin (Fairbanks, Alaska) and H. B. Zachry (San Antonio, Tex).

NIKE ZEUS



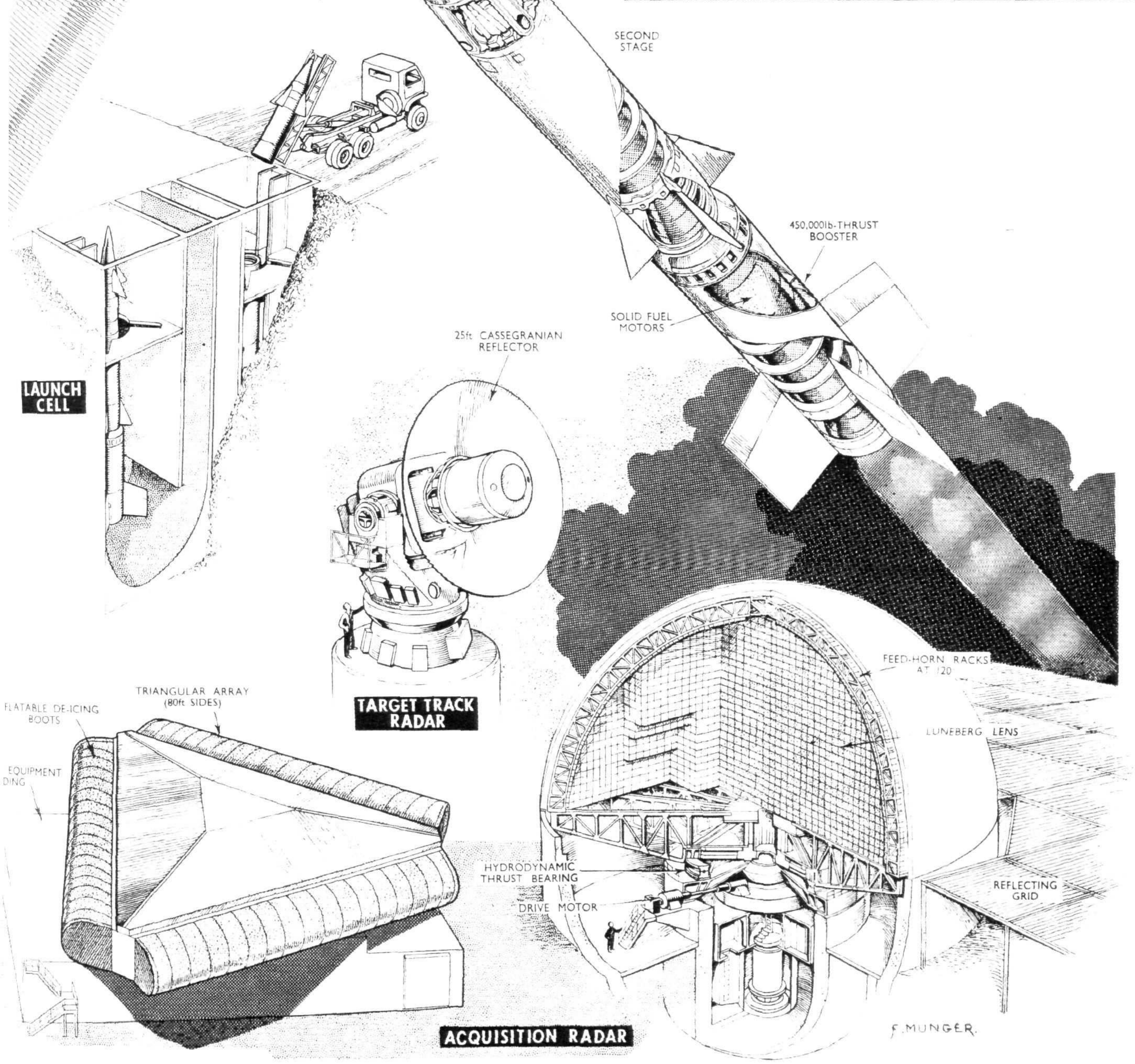
100sec (500 miles)
ACQUISITION
RECEIVER
TRANSMITTER
DETECTOR DATA-PROCESSING
WARHEAD
GUIDANCE DATA-PROCESSING
DR
TTR
MTR
IRBM
ICBM
Midway
Wake
Eniwetok
AICBM
Hawaii
RECOVERY AREAS
POLAR ORBIT
Kwajalein
Christmas
Manus
EQUATORIAL ORBIT
SECOND STAGE
BOOSTER
LAUNCH ORDER
LAUNCH CELLS
BATTERY POWERPLANT
TARGET TRACK RADAR
MISSILE TRACK RADAR
DISCRIMINATION RADAR
INSTRUMENTATION
ACQUISITION RADAR
RANGE CONTROL AND COMMUNICATIONS
POWERPLANT

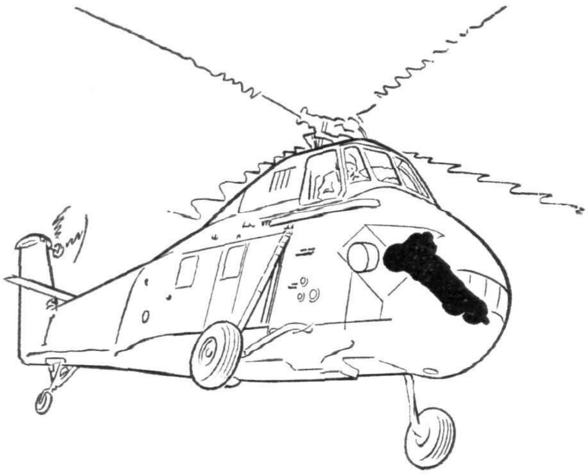


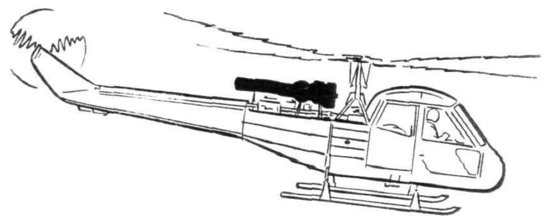
On the left-hand page is a schematic representation of an interception by Nike Zeus similar to that of an Atlas target vehicle on July 19. The 16,000 m.p.h. target may be seen coming in from right to left along the top of the page and being tracked successively by the acquisition, descrimination and target-track radars on Kwajalein Atoll. A nuclear fireball in outer space marks the point of interception, which occurs 170sec from first detection. In this time the target moves over 850 miles

NIKE MISSILES

Missile	Ajax	Hercules	Zeus
Boost motor	Single solid	Quad solid	Single solid, 450,000lb
Sustainer	Acid/aniline, 2,600lb	Solid	High-impulse solid
Controls	Canard	Rear-mounted on wings	Canard (atmosphere) Jethead (in space)
Warhead	Three h.e.: 300lb total	H.e. or nuclear	Nuclear, about 1MT
Missile length	21ft 2in	27ft	32ft 6in
Missile weight	1,150lb	5,200lb	About 10,000lb
Length plus booster	*35ft 6in*	*39ft 2in*	*48ft 4in*
Weight plus booster	2,455lb	10,400lb	22,000lb
Body diameter	12in	32.2in	45in
Max Mach number	2.25	3.65	11
Max slant range	25 miles	80 miles	Over 150 miles
Max altitude	12 miles	29 miles	About 150 miles
Production	1952-1957	1957-1960	R & D only
Deliveries	15,000	About 15,000	200+
Firings	5,500	About 3,000	30-35







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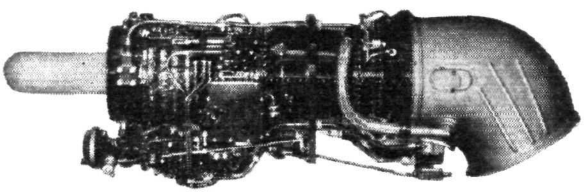

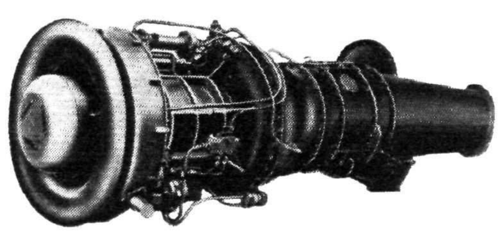

GNOME

The versatile **Gnome** is in service in Westland Whirlwinds and in Agusta Bell 204B helicopters. Coupled **Gnomes** are flying in the Westland S.58 Wessex Mk.2. **Gnome** engines have also been supplied to Italy for installation in the new three-engined Agusta 101G large transport helicopter and for the Vertol 107 helicopter being supplied to Sweden. The **Gnome** is being further developed to meet the higher power requirements of future helicopters.

NIMBUS

The **Nimbus** (A.129) free turbine engine has been ordered in quantity for the Westland Scout, a new general-purpose helicopter for the Army, and Westland Wasp, the naval version. Four **Nimbus** engines power the advanced 25-ton Westland SRN 2 Hovercraft.

Following the integration of the Blackburn and de Havilland engine companies with the Bristol Siddeley organisation, Bristol Siddeley now offer a unique range of small gas turbines. These successful products, already established in a wide variety of applications, are now backed by the resources of one of the world's largest aero-engine manufacturers.

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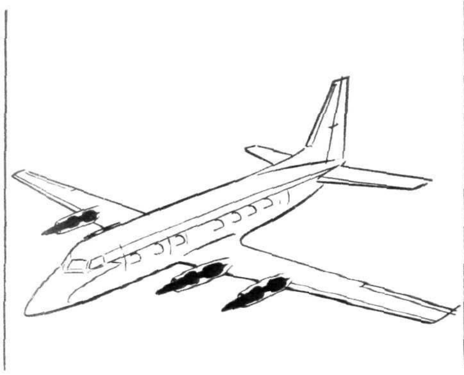
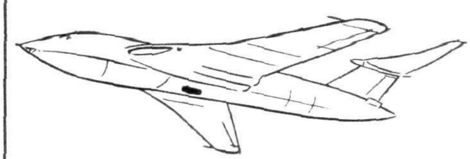
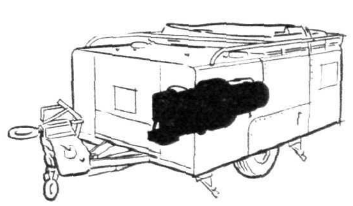

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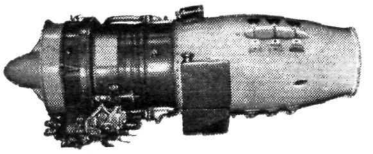

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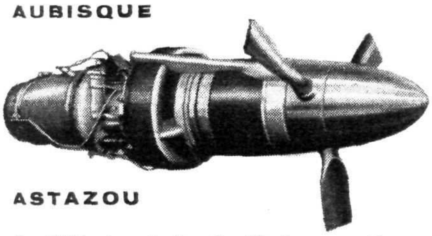
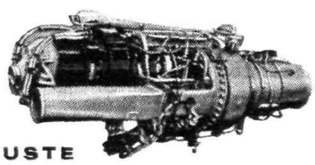
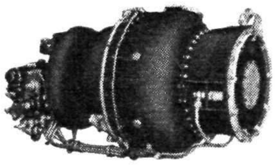


ASTAZOU

As U.K. Agents for the Turbomeca Company of France, Bristol Siddeley are now collaborating with Short's on the Skyvan Mk.2 for which the **Astazou** engine has been chosen. The **Astazou** turboprop and the new **Aubisque** turbofan combine high performance with economy, and are designed for light aircraft.

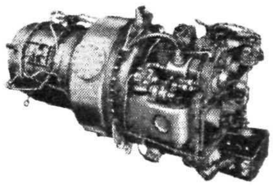


ARTOUSTE



CUMULUS

The **Artouste** airborne auxiliary power unit is now in service in the Canadair C.L.44, providing air starting for the main engines and other supplementary power. The Victor B. Mk.2 and the Trident carry **Artouste** engines for low-pressure air and electrical services, and the engine has also been ordered for the Short Belfast Freighter. The new **Cumulus** engine, designed for the same role, cuts weight and overall size still further to meet the more stringent specifications that will be called for in future aircraft.



PALOUSTE

A large number of **Palouste** low-pressure air starters, installed in self-contained trolleys, are in service with the Royal Air Force, the Royal Navy, the Ministry of Aviation and all the major aircraft and aero-engine manufacturing companies in the United Kingdom. A streamlined "pod" version, which can be carried externally on aircraft, has also been developed for the Royal Navy.

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At the moment the Zeus **DR**, discrimination radar, is far from finalized and is in any case highly classified. But it will obviously be a multi-megawatt equipment, with a variable-beam aerial able to pick the right object out of the decoy cloud.

Precise data on the plummeting target are then fed to the **TTR**, target-track radar, which fires a powerful pencil beam from a 25ft reflector in a 40ft geodesic radome. One TTR is needed for each target, and it has to combine high power in the narrow beam with extreme accuracy in its mounting and drive; for example, the angular tolerance between any tooth in the azimuth drive gear and any of its 1,343 neighbours is 3.4sec of arc.

TTR data are fed to the **TIC**, target intercept computer, the task of which is to determine the target trajectory, examine it against the characteristics of the Zeus missile and launch the latter at the precise instant for an optimum interception. To accomplish this in 10sec would demand no mean computer; but what lifts the TIC head and shoulders above any other data-processing equipment known is that, to all intents and purposes, it must never go wrong. The design failure rate for the switching transistors and carbon resistors is 0.01 per 1,000hr, and the figure set for the entire installation is 600 operating hours with no component failure. According to the firm which developed it: "A permanent twistor memory and a ferrite-core scratch-pad memory are vital to reliability, assuring continuous operation until an attacking missile is intercepted and destroyed. Decisions are made in microseconds. Built-in error-detection circuitry and unique modular construction have resulted in nearly automatic maintenance." After the signature has been isolated by the DR the TIC compares it with all the known signatures held in storage. Withdrawal from store requires 0.0000028sec and complete calculations can be performed at the rate of 200,000 per second.

Data from the TIC are continuously fed to the **MTR**, missile-track radar, which is essentially a refined and more powerful version of the INH counterpart. Missile assignment and warmup are signalled by the TIC, and at the exact moment the launch order is transmitted to the selected "bird." The boost thrust of 450,000 to 500,000lb imparts an initial acceleration in excess of 20g, rising to more than 35g at booster burnout 6sec later. Departure from the controlled-environment silo is vertical, but after ignition of the sustainer the MTR pulls the Zeus round towards the pre-computed point of interception. At the appropriate height and speed the thermonuclear warhead is armed and fuzed, and it is detonated by MTR command.

During the initial flight test phases at White Sands, the Zeus missile had a jagged hypersonic configuration with wedge-shaped aerodynamic controls mounted around the tips of slender delta wings. Results showed that the configuration could be improved—and a few vital seconds lopped off the time to the kill point—by removing the wing entirely, and the present missile has forward-mounted controls and fixed fins at the rear. Unlike any other interception missile Zeus must also manœuvre above the atmosphere, in order to steer directly at the finally refined intercept point in space, and to achieve this it has a "jet-head" third stage containing a spherical-bottle motor discharging through four jetevator nozzles.

Construction of the airframe is relatively conventional, 24 ST aluminium alloy being the ruling material. The most unusual feature is that the tremendous acceleration results in hypersonic speeds being reached while still in relatively dense air, and this has necessitated the achievement of an absolutely uniform surface finish, with no discontinuities—such as skin joints or bolt holes—and with the entire exterior sealed by an ablative insulating coating. Phenolic-resin bonded Refrasil protects local surfaces subject to exceptionally high angles of attack, such as the nose and leading edges. Motor cases are generally of modified 4340 stainless steel, and the motor nozzles of glass-reinforced plastics with an ablative liner.

Although initial flight testing of the Zeus missile was conducted at White Sands, New Mexico, the Army had to defer full-range testing of the complete system until a Zeus installation had been constructed at Point Mugu, at the head of the Pacific Missile Range. As the table of firings shows, many successful launches have now been made with the three-stage Zeus guided by a simulated "signature" fed into the TIC by magnetic tape, and the test on July 19 differed only in that the TIC input was obtained from a live target. The re-entry vehicle on this occasion was a special design by General Electric, first flown last November 21 on a Titan 1 but flown on an Atlas on July 19.

Since the end of 1956 Nike Zeus has been the centre of a fierce controversy embracing engineers, senators, civil servants and a posse of generals dressed in both khaki and light blue. At the time of writing, the Zeus remains an active programme, with a current funding of $267.5m (£96m) for fiscal year 1963. But its detractors are numerous, and this journal will not be the first authority to leave the decision of whether or not to make it to somebody else.

ZEUS TIMETABLE

Date	Location	Event
1955	Whippany	Initial studies by Bell Telephone Laboratories.
1956	Huntsville	ARGMA issue R & D contracts to Western Electric, BTL and Douglas for basic research.
Spring '57	Washington	US Army authorize Nike Zeus as full-scale development programme.
Mid-1958	US	Principal design goals defined, major R & D advances successfully achieved and basic design of all elements at advanced stage.
May 1959	Beaumont	Successful static firing of sustainer.
August '59	WSMR	Launch of early test model; structural failure.
14-10-59	WSMR	First successful test; short of planned range.
16-12-59	WSMR	Early test model, live booster and sustainer.
3-2-60	WSMR	Early test model: success.
-3-60	WSMR	Early test model; success.
28-4-60	WSMR	Early test model, first launch from R & D underground emplacement.
23-5-60	WSMR	Early test model, completed this programme.
10-8-60	WSMR	First launch of improved configuration; malfunction after boost separation.
-12-60	WSMR	Launch of special test round (early model with wings removed) from underground emplacement.
16-1-61	Asc	First checkout of test TTR installation.
10-2-61	WSMR	Live second stage.
28-4-61	WSMR	Special test round (early model with wings removed) from prototype underground emplacement.
27-5-61	Asc	TTR tested for first time against real target (Atlas).
26-7-61	WSMR	First test of complete missile from operational launcher and also first test with trajectory controlled by programmed-tape guidance.
25-8-61	WSMR	Test shot with taped guidance over extended range; complete success.
9-9-61	PM	First shot down PMR; self-destruct at 20sec.
15-9-61	WSMR	High-velocity atmospheric test, with taped guidance.
7-10-61	PM	Self-destruct shortly after second-stage ignition.
15-11-61	WSMR	Two launches, both with taped guidance, the second from operational launcher.
17-11-61	PM	Synthetic interception, above-atmosphere trajectory, high-impulse Thiokol sustainer.
21-11-61	PM	Synthetic interception, high-impulse sustainer.
30-11-61	WSMR	First with live jethead third stage.
9-12-61	PM	Shallow-angle firing over extended range.
14-12-61	WSMR	Interception of Nike Hercules on descending ballistic trajectory; spotting charge burst well within lethal radius of Zeus warhead.
14-12-61	PM	Extended-flight test; longest and highest flight to date.
14-12-61	Kwaj	First test at this location to prove launcher; success.
28-1-62	PM	Synthetic interception; first success at long range.
1-2-62	WSMR	Three-stage manoeuvre at low altitude; success.
7-2-62	WSMR	Two-stage firing from operational launcher; success.
12-2-62	PM	Synthetic interception; guidance response but self-destruct at 20sec.
5-3-62	Kwaj	Successful synthetic interception.
8-3-62	PM	Three live stages; manual command destruct at 7sec when crossed N limit of safe corridor.
13-3-62	WSMR	Two synthetic interceptions; operational launcher.
28-3-62	WSMR	Interception of Nike Hercules on descending ballistic trajectory; success.
5-4-62	WSMR	Synthetic interception of ICBM; success.
12-4-62	PM	"Extremely high altitude" test; success.
19-4-62	PM	Synthetic interception; self-destruct during second-stage propulsion.
27-4-62	WSMR	All three stages functioned perfectly.
30-4-62	WSMR	Automatic firing on synthetic interception; success.
1-5-62	WSMR	Synthetic interception; success.
26-5-62	PM	Full three-stage test; success.
16-7-62	WSMR	Synthetic interception; success.
19-7-62	Kwaj	Interception of re-entry vehicle of Atlas ICBM fired from Vandenberg AFB; success.

Notes: Asc, Ascension Island; Kwaj, Kwajalein Atoll; PM, Point Mugu; WSMR, White Sands Missile Range. This table has been compiled by the author, and is in no sense an official document.