Reports: Davies: Insp by Sm Satl

INSPECTION BY SMALL SATELLITES

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INTRODUCTION

Within the next five years, a number of nations will have developed space booster capability. This will permit these countries, if they choose, to launch and operate satellites to take pictures of the earth from orbit. Observation satellites of this type are capable of inspecting the compliance of all nations to arms control agreements. To be useful for this purpose, these pictures must be somewhat better in quality than those which have been taken by meteorological satellites and orbiting cosmonauts. The ground resolution of pictures taken thus far is measured in miles or in hundreds of feet, whereas pictures used to inspect man-made facilities should have a ground resolution measured in tens of feet. In fact, such performance (i.e., a ground resolution of 10-50 ft) could be realized by relatively small (250 lb) payloads employing available modern optical techniques.

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SATELLITE LAUNCHER PROLIFERATION

Space boosters have been developed by the United States, the Soviet Union, and France and are under development by the European Launcher Development Organization, Japan, and Great Britain. The United Arab Republic has also announced a satellite project, and other countries, such as China, India, and Germany, may be expected to proceed with independent space programs in the near future. Moreover, Italy, South Africa, Canada, Indonesia, and Israel have active rocket projects which might eventually lead to the development of their own space boosters. It appears that during the second decade of space operations many nations will be eager to participate in the development of space systems.(1-4)

The multi-nation European Launcher Development Organization is developing the three-stage booster, Europa 1, sometimes called ELDO A. Britain is responsible for development of the first stage, France for the second stage, and West Germany for the third stage. Italy is responsible for the test satellites, Belgium for downrange guidance, the Netherlands for telemetry, and Australia for the range facility at Woomera. Although the cost of this program has been much higher than estimated, test firings are proceeding and should result in orbiting a satellite in 1968.(5,6)

Currently, French satellites are placed in orbit by the Diamant booster launched from the missile test range at Hammaguir, Algeria, in the Sahara Desert. This range must be abandoned by July 1, 1967, according to the terms of the French-Algerian treaty, and a new French space center and launch site is being built near Kourou in French

Guiana, about five degrees north of the equator. This range should be operational by the beginning of 1969, and because of its favorable location, it should be capable of supporting the launch of satellites in both polar and equatorial orbits.(7,8)

The Japanese are expecting to orbit a satellite by early 1968 using their Mu 4 booster. It will be fired from the Mu pad at the Kagoshima Space Center on the southeastern tip of Kyushu Island. All four of the solid rocket stages have been test fired individually, and the guidance and control system is currently being tested. Japan should be the fourth nation to participate in satellite operations.(9)

The British have been slow to support a domestic satellite program. However, in the fall of 1965 the Conservative government approved development of the Black Arrow booster. This was conceived as a further development of the highly successful Black Knight high-altitude rocket program, and it used much of the technology developed for that vehicle. The Labor government has given only limited support to this program, so a meaningful flight schedule is not available.(10,11)

In 1963, the United Arab Republic announced plans to launch a satellite called The Star. It was assumed that the booster would be an extension of their Al Ared missile. Although launch of The Star is overdue, there are reports that the program has not been abandoned.(12,13)

AN INSPECTION SATELLITE DESIGN

These new boosters will be able to orbit only small payloads, so a design study of a particular inspection satellite has been used in order to test the feasibility of developing a lightweight system. Since minimum weight is a requirement, a spin-pan type of camera was selected.(14) This panoramic camera operates from a spin-stabilized vehicle, and the spinning performs the cross-track scan of the camera as the film is moved across a slit located at the focal plane. This takes place at a velocity which compensates for the spin during exposure. Thus, a wide-angle picture is obtained by scanning with a simple narrow-angle lens. The film velocity is determined by a sensor which measures the satellite spin rate. This can be accomplished by a horizon sensor, a sun sensor, a gyroscope, or ground measurement. The spin axis can be changed by magnetic torquing, as is being planned for the French D-2.(15) All Tiros satellites change their spin axis in this manner.(16) Passive dampers can simply and easily keep any nutation angle small.

This camera could be designed to take several pictures on film each day for 100 days. The film would be processed in the satellite, electronically scanned, and the pictures transmitted to ground stations by broadband telemetry. The Soviet space probes Lunik III and Zond 3 produced pictures of the moon in essentially the same manner. Figure 1 is an external view of the proposed spacecraft showing the camera lens and the solar cell panels. Figure 2 shows the internal configuration of the camera, which would have a catadioptric lens with a focal length of 30 in.

Since the spin axis lies in the orbital plane, it would be parallel to the surface of the earth only twice on each revolution of the earth (see Fig. 3); consequently, the direction of the spin axis should be programmed so that it is horizontal over the desired inspection area. If the camera operates through a 70° scan, then an area 350 by 45 n mi would be photographed from an altitude of 250 n mi in a single pass (see Fig. 4).

After the film had been exposed, it would be processed in the satellite by a web developer and then stored to await readout. When the satellite passed within range of a receiving station, the film would be scanned, and the pictures transmitted to the ground. Tables 1 and 2 present the design characteristics of the camera and readout systems. The ground resolution to be expected of this design would be about 20 ft at 125-n mi altitude and 40 ft at 250-n mi altitude (see Fig. 5). A weight breakdown of the entire satellite is given in Table 3.

USE OF THE INSPECTION SATELLITE

Photography with a resolution of 10-50 ft would be useful for arms control. It would be useful to inspect military facilities such as forts, military bases, airfields, munition storage, docks, naval installations, and missile ranges, as well as manufacturing facilities for weapons and delivery systems.

In order to illustrate the capabilities and limitations of this photography, selected pictures of Cuba taken by U-2s during the missile crisis of 1962 were rephotographed to control the resolution to simulate satellite photography. Figure 6, a photograph of San Julian Airfield in Cuba, shows this base as it would appear with a ground resolution of 20 ft. The runways, taxiway, parking areas, hangar facilities, and hardstands can be easily seen. However, individual aircraft, trucks, trailers, and aircraft cannot be readily identified. The SA-2 site can be located very easily, but its operational status cannot be determined. The mobile SA-2s being used in North Vietnam certainly would not be detected.

Figure 7 shows the construction of the IRBM base at Remedios, Cuba, as it would appear with a ground resolution of 40 ft. It is clear that the missile complex would be detected during construction. The characteristic road and cabling between the launch pads and control bunkers, the security fence, and the support buildings serve to identify the nature of the facility. However, it is difficult to determine the status of the construction or to ascertain when the base will become operational. It is obvious that the destruction of the base which occurred shortly after these pictures were taken could not have been observed from this type of picture.

Inspection by satellite can make a valuable contribution to world peace by aiding in the disclosure of military buildups and of violations of certain arms control agreements.

ACKNOWLEDGMENT

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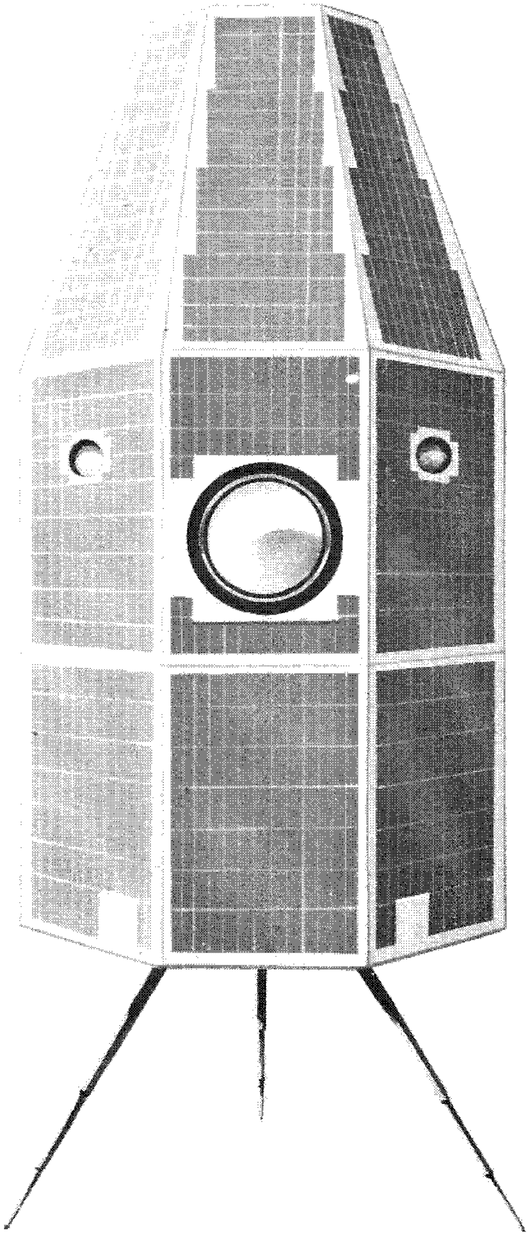


Fig. 1—Inspection satellite—booms unextended

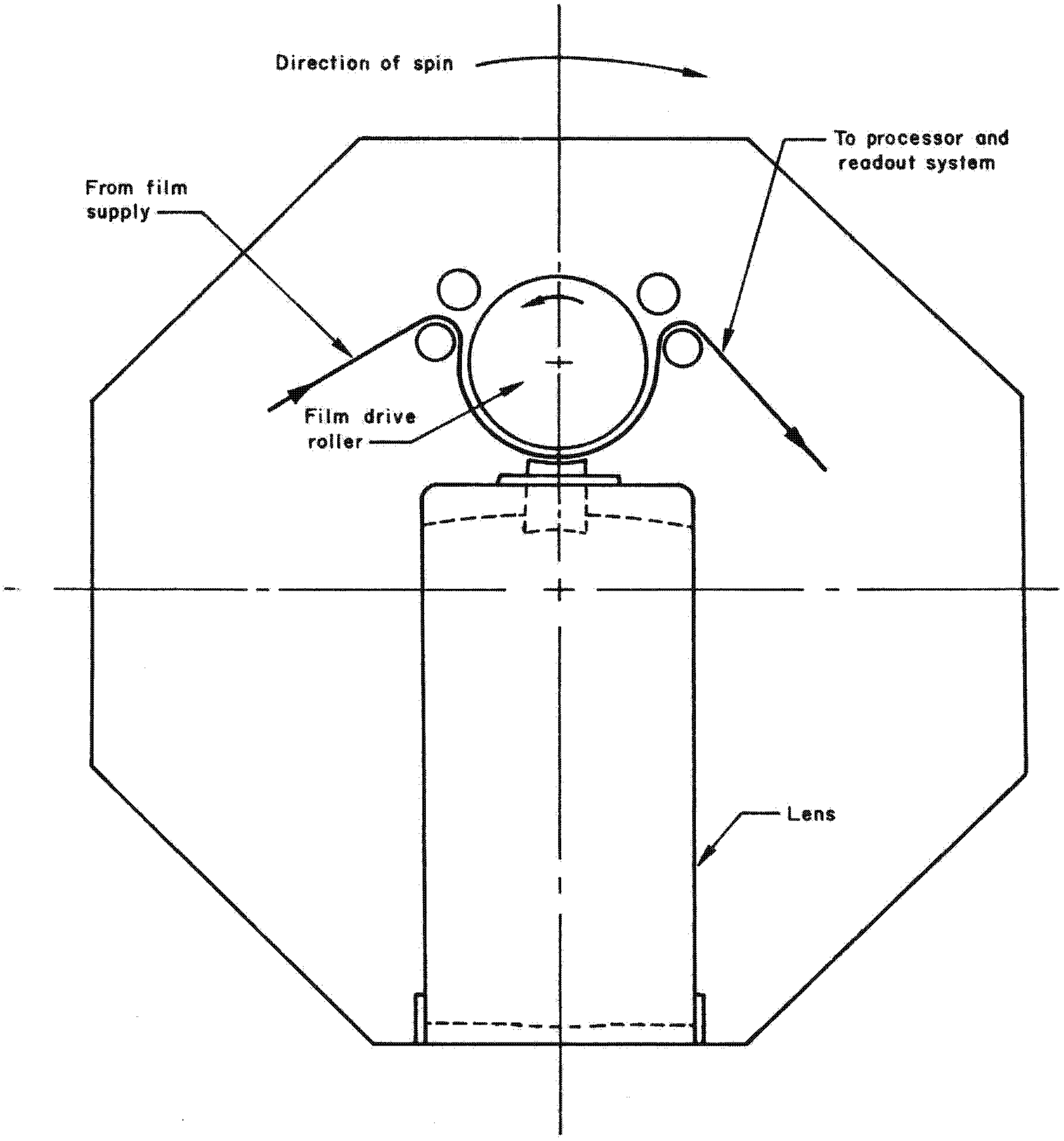


Fig. 2—Spinning panoramic camera

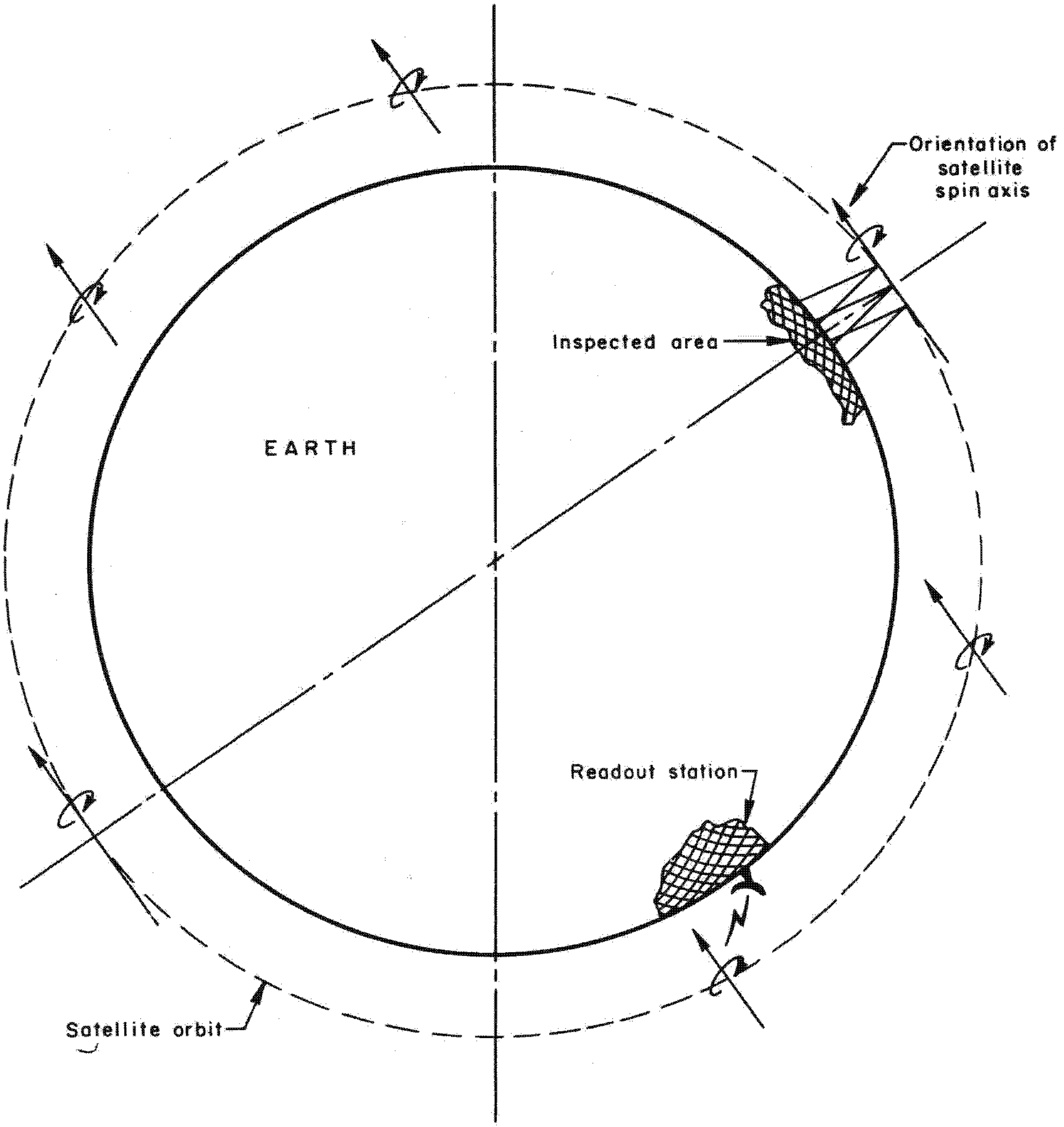


Fig.3—Schematic illustration of satellite operation, showing alignment of satellite's spin axis

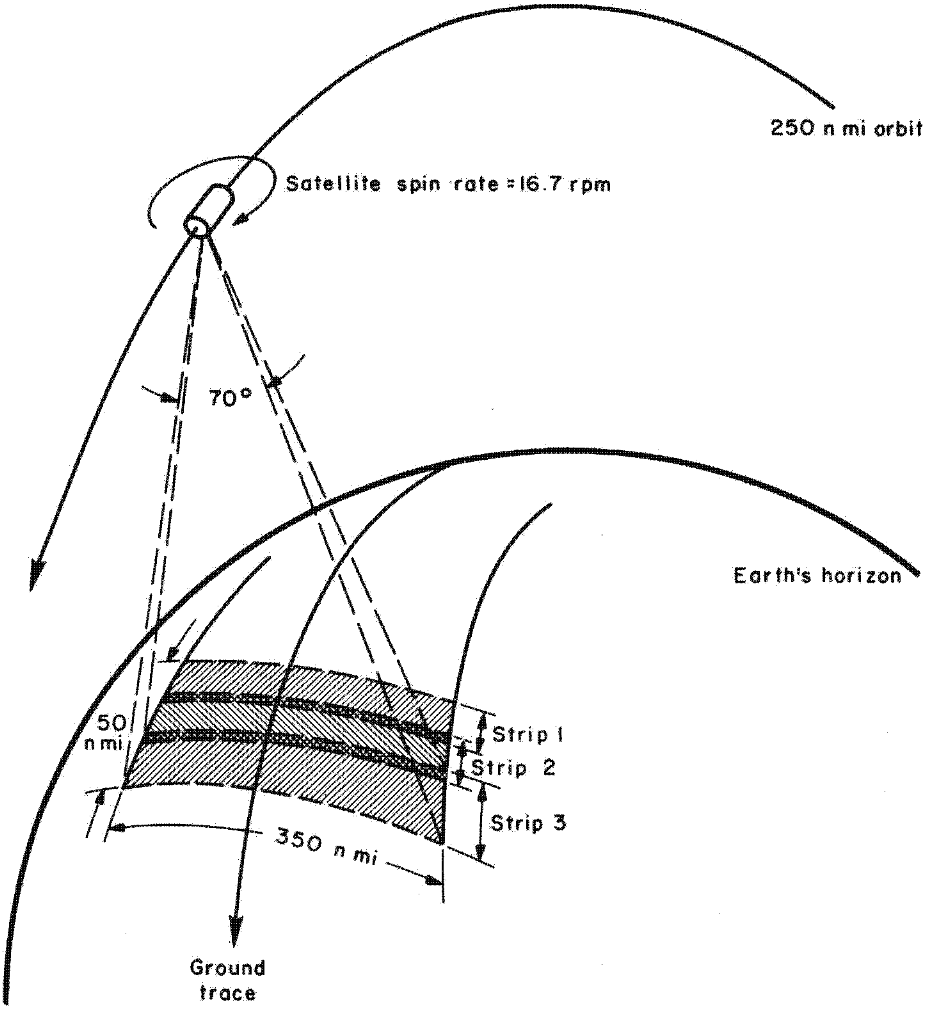


Fig.4—Ground coverage pattern

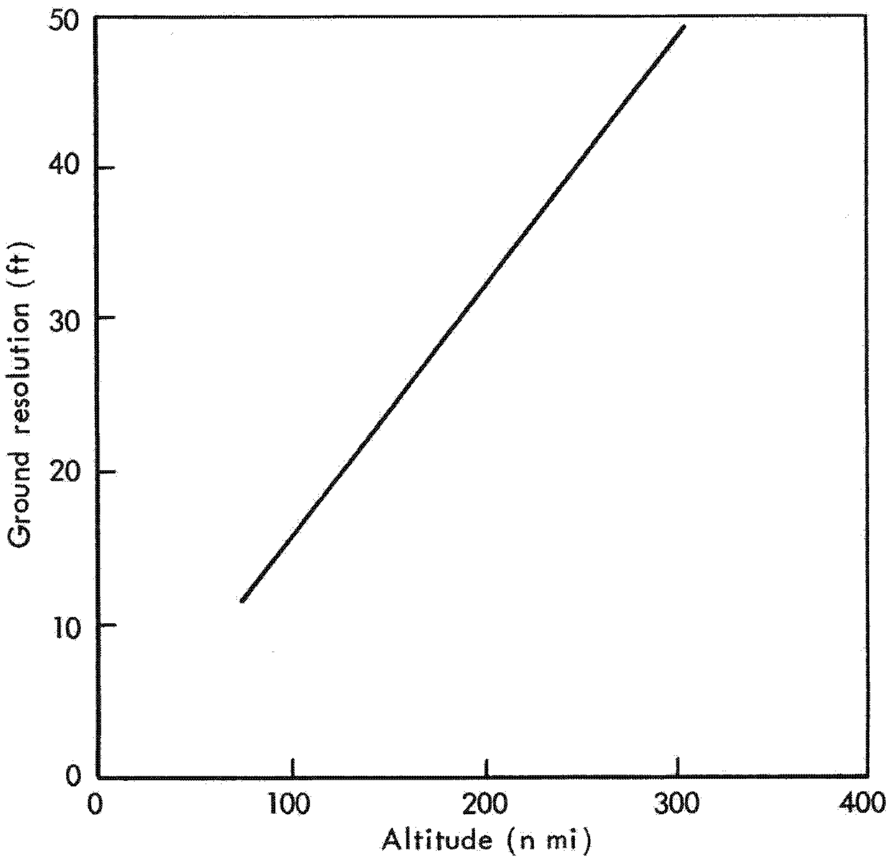


Fig.5—Ground resolution as a function of altitude

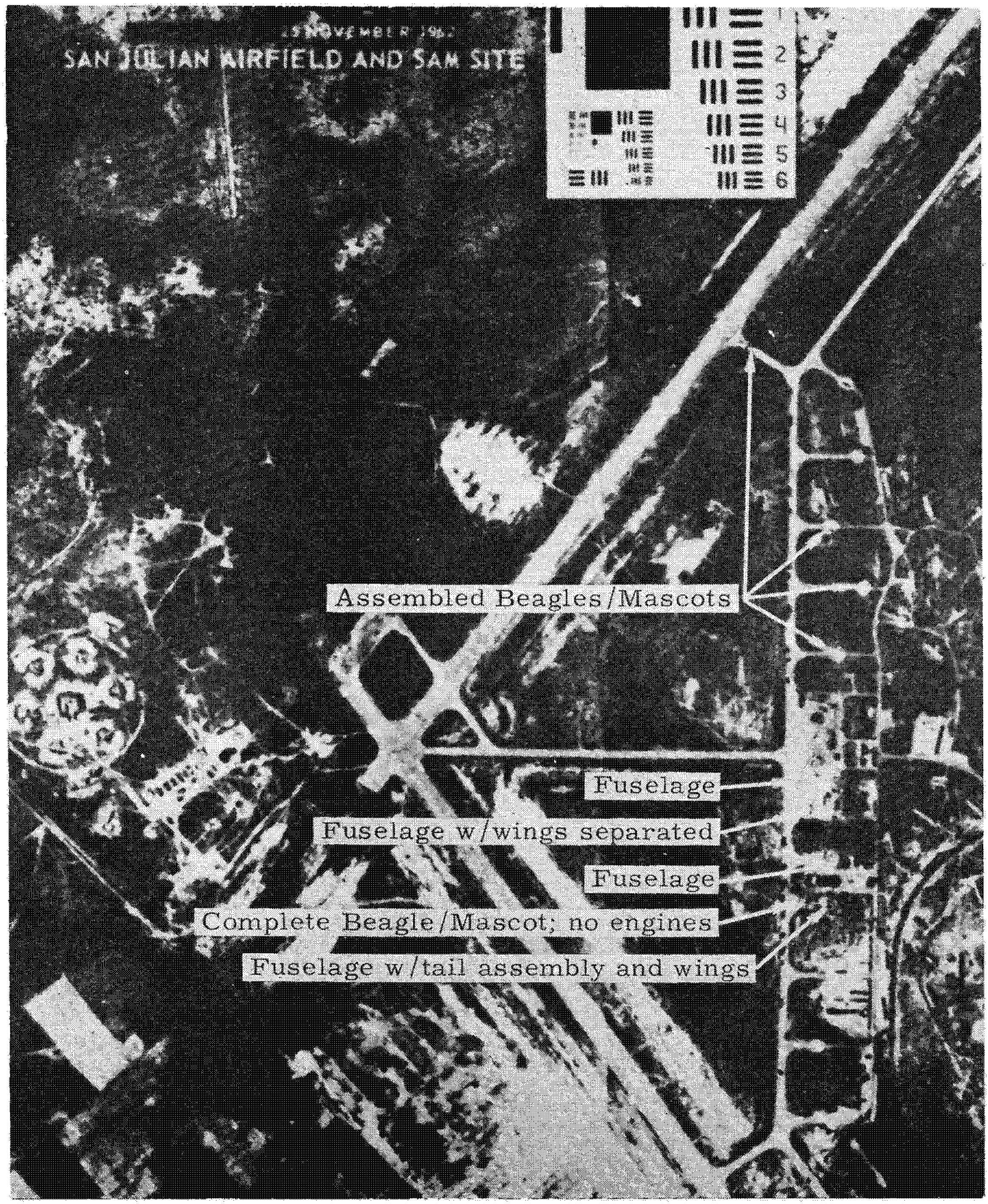
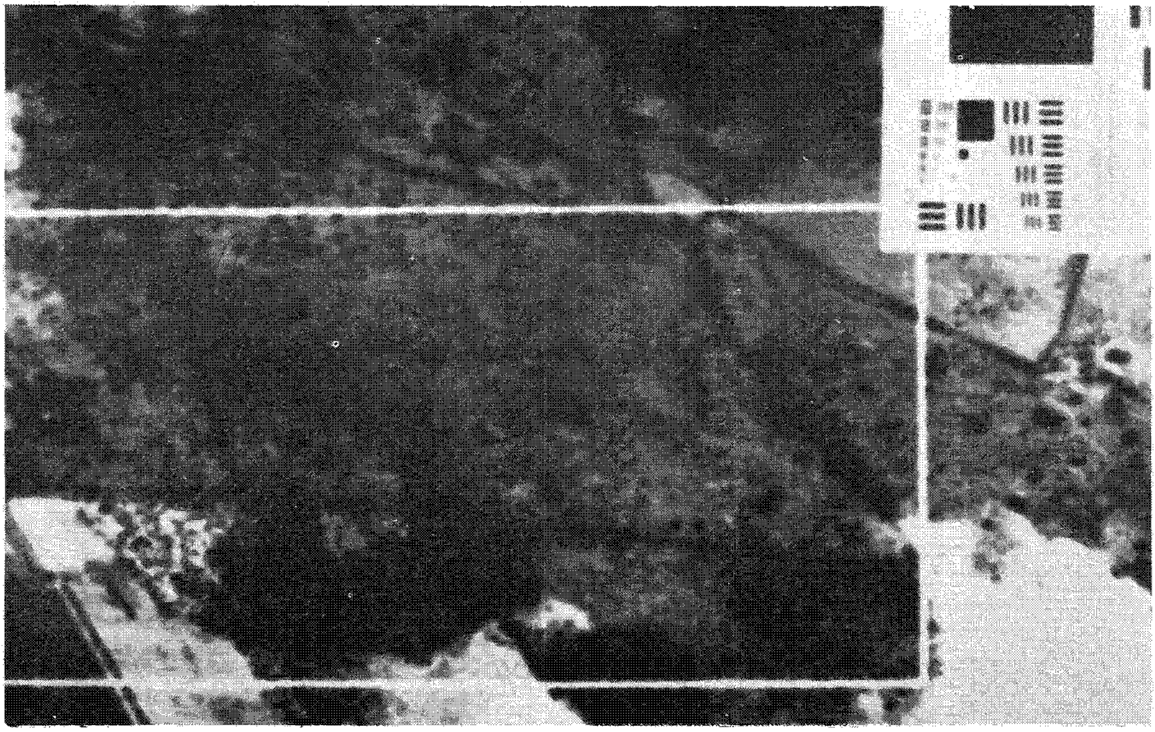
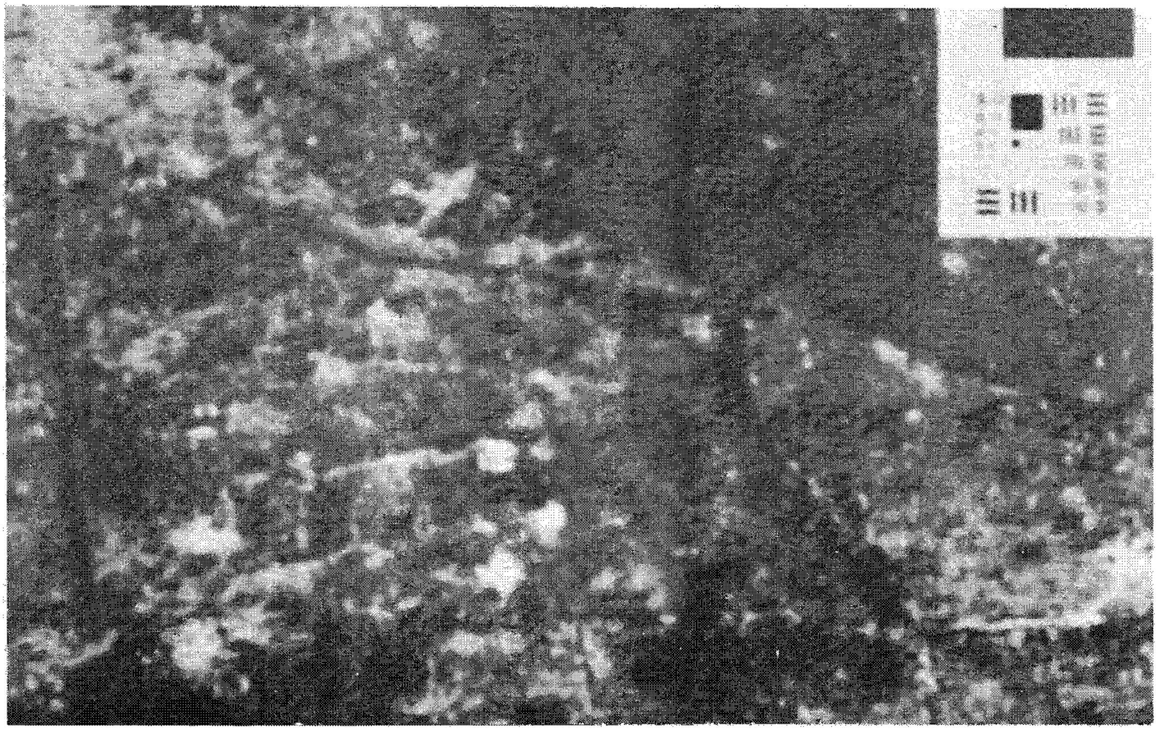


Fig. 6—San Julian Airfield, Cuba, 25 November 1962
(20-ft resolution)

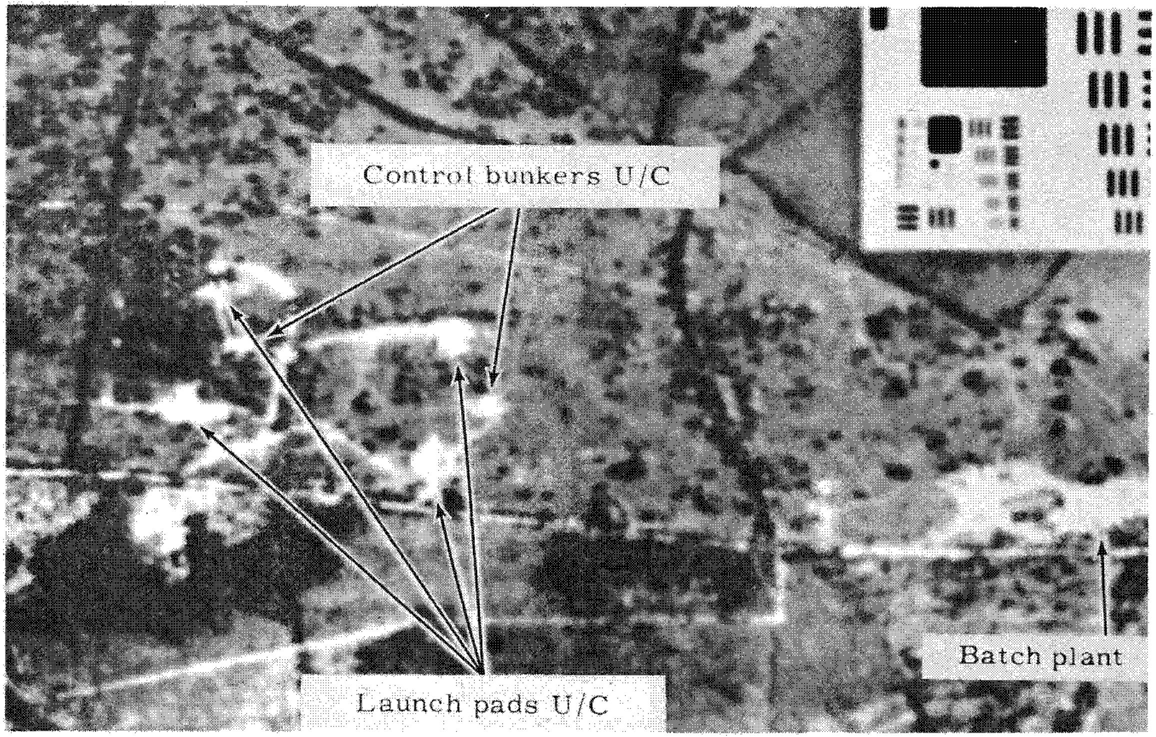


(a) Before construction, 5 September 1962

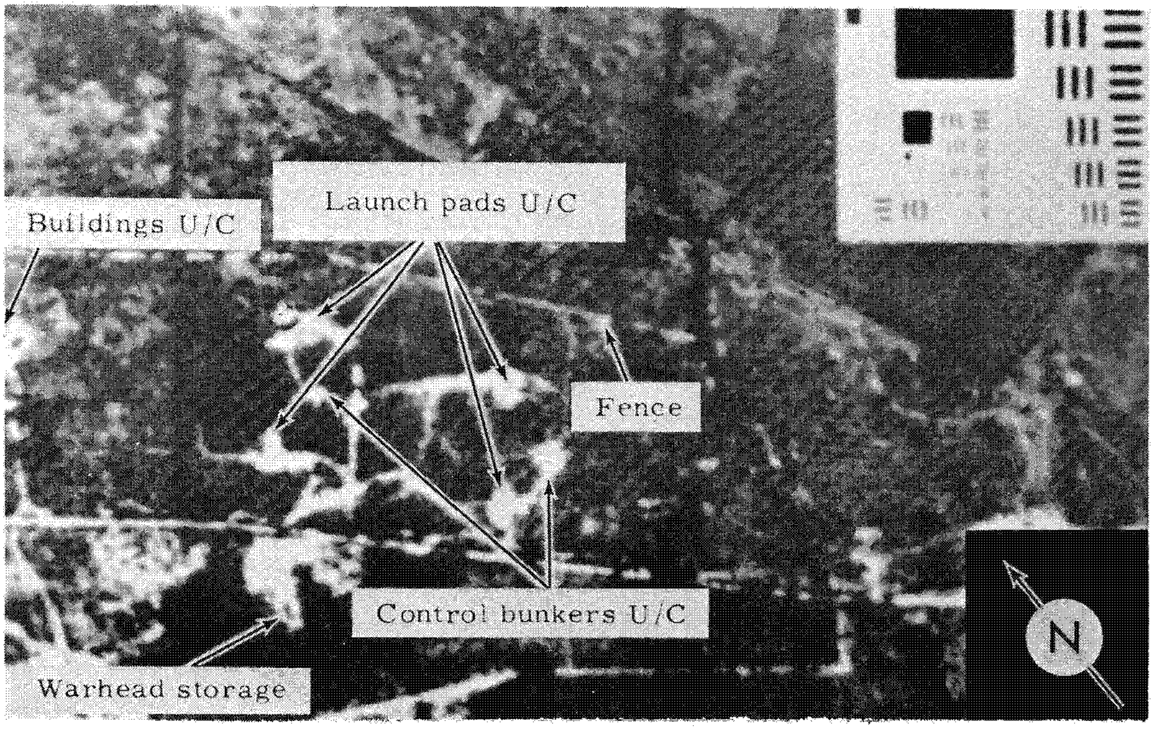


(b) Construction under way, 17 October 1962

Fig.7—IRBM site at Remedios, Cuba (40-ft resolution)



(c) Construction continuing, 19 October 1962



(d) Later construction in progress

Fig. 7 (continued)

Table 1

READOUT CAMERA CHARACTERISTICS

Lens	30 in. catadioptric, f/4.5
Format	2.25 in. by 36.6 in.
Scan angle	70° (±35° from nadir)
Film	70 mm, SO-136 or equivalent
Film speed	ASA 20
Exposure (nominal)	1/1500 sec, preset before flight
Slit width	0.030 in., fixed
IMC (Image motion compensation)	fixed, cam action
Cycling rate	3.6 sec
Mode of operation	3 strips in sequence
Forward coverage	20% overlap set center of frame

Table 2

READOUT CHARACTERISTICS

Resolution	50 line pairs/mm
Scan rate	860/sec
Rate of film motion	c. 0.50 in./sec
Video bandwidth	c. 4.5 Mc

Table 3

ESTIMATED WEIGHTS

Component	Weight, lb	
Camera Installation		
Lens and lens mount		25
Film transport assembly		20
Film	10	
Film reels (supply and takeup)	3	
Scan roller assembly (including drive)	3	
Structure	4	
Developer processor		19
Developer (film and web)	12	
Reels (supply and takeup)	3	
Drum drive	2	
Heater assembly	2	
Readout installation		40
Readout scanner	20	
Drum and drive	3	
Electronics	17	
Structure		12
Base plate	6	
Exterior	3	
Supporting structure	3	
Instrumentation and cabling		5
Pressurization system (including gas for heater/dryer)		5
Electrical Power		
Solar cell panel assembly		35
Batteries and case		10
Converters, regulators, and distribution unit		5
Cabling, connection, and J-box		5
Stabilization System		
Horizon sensors		2
Aux-spin rockets		10
Nutation damper		2
De-spin assembly		5
Electronics		
Command receiver		5
Programmer		5
Data transmitter		10
Antennas		3
Cabling		5
Instrumentation		2
Structure (not including camera section)		
Equipment support		3
Supports for solar panels		8
Adapter and separation mechanism		6
Miscellaneous hardware and attachments		3
Total		250

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