Functions: NASA
Studies: (Hippert) Various
Sensor Platforms for
NASA Multiband Experiment

CONSIDERATION OF VARIOUS SENSOR PLATFORMS

FOR

THE NASA MULTIBAND SYNOPTIC

PHOTOGRAPHIC EXPERIMENT PROGRAM

HANDLE VIA
BYEMAN-TALENT-KEYHOLE
CONTROL SYSTEMS JOINTLY

Approved for Release: 2017/01/25 C05096424

I. The NASA Multiband Synoptic Photographic Experiment Objectives

A. Agriculture and Forestry

Feasibility and Research Phase:

1. To determine and define the potential scientific/economic value of performing agricultural and forestry research from space relative to the following:

a. Assessment of crop and timberstand vigor and prediction of future yields.

b. Recognition and establishment of the relationships among productivity, distributions, and concomitant natural and man-made phenomena.

2. To develop spatial and spectral signatures for plants, animals and soils.

Operational Phase:

To gather data utilizing spaceborne instruments, for the purpose of increasing agricultural and forestry production to meet the needs of an expanding population.

B. Geography and Cartography

Feasibility and Research Phase:

To determine and define the potential scientific/economic value of performing geographic/cartographic research from space relative to the following fields and activities:

1. Thematic mapping and studies to include:

   a. Land use

   b. Population distribution and changes

   c. Transportation

   d. Property delineation (cadastral mapping)

   e. Other relationships and interactions of natural and cultural resources with the activities of man.

2. Topographic mapping and cartographic expression as required to support thematic mapping.

3. Determination of the size and shape of the earth, and the extent to which continental and local spatial relationships are time variant.

Operational Phase:

To gather data from space on a continuing basis for the purpose of providing mankind with timely information relative to his relationships and interactions with natural and cultural resources.

C. Geology

Feasibility and Research Phase:

To determine and define the potential scientific/economic value of performing geological research from space by the following:

1. The study of the dynamic qualities of the Earth's surface and crust with an aim toward developing an ability to predict earthquakes, volcanic eruptions, and toward achieving a better understanding of the forces that deform the Earth's crust.

2. The development of a global framework of geologic-geophysical knowledge within which to place our more detailed terrestrial scientific observations against which to test our scientific hypotheses, and by which to discover additional mineral resources.

3. The study of the processes which shape the Earth's surface including sedimentation, deposition and radiation, and the interrelationships of these parameters with time and climate, with the aim of improving our knowledge of the Earth, its surface, its engineering properties and its mineral resources, and enhancing our ability to determine the history of other planetary surfaces.

4. To define the Earth in terms of its magnetic, gravitational, and radiation fields; heat balance, other parameters; and internal constitution -- especially in terms of the relationship of the mantle, crust,

and subcrustal layers. To apply this knowledge to improve our understanding of the Earth's origin, its mineral resources, its relationship to other planetary bodies, and to the origin of the solar system.

Operational Phase:

To inventory and monitor the mineral resources of the Earth and thereby assist in better management and utilization of these resources in meeting the compounding demands and desires of people created by the rapid advances in technology and population expansion.

D. Hydrology

Feasibility and Research Phase:

To determine and define the potential scientific/economic value of performing hydrologic research from space by the following:

1. The study of hydrologic features, cycles and processes.

2. The measurement and distribution of rain and snowfall, runoff and water retention in drainage basins of differing size, topography and geologic environment. Such measurements will include variations of cooling and subsequent heating of the Earth after a rainfall.

3. The measurement of the salt water content of natural waters in estuaries and other waters used as supplies for municipal, industrial and irrigation purposes.

4. The development of techniques for monitoring water pollution on a rapid, repetitive and synoptic scale.

5. The conduct of studies relative to evapotranspiration, or the loss of water from soil and vegetation into the atmosphere. This will be done by determining: (a) how water vapor entering the atmosphere can be measured from space; (b) what quantities are lost and when, in terms of diurnal and seasonal periods. When this is established, to determine the relationship of evapotranspiration to growth of crops and to antecedent soil moisture conditions.

6. The identification of areas of ground-water discharge and measurement of contributions to surface-water bodies. Identification of such discharge areas should assist the search for areas underlain by aquifiers capable of supplying water for municipal, industrial and irrigation use.

7. The investigation and identification of subaqueous features of large lakes and reservoirs such as bottom topography and current movements and their effects on the distribution of sediment and biota.

8. The location, extent and effects of culturally accelerated erosion and sedimentation.

Operational Phase:

1. The inventory and assessment of the water resources of the nation and the world.

2. The mapping of the distribution and measurement of the contribution of fresh water and sediment from the continents to the ocean basins.

3. The utilization of the synoptic and repetitive capability of orbital sensing to monitor the water regimes of glaciers, snow fields and ice caps as sources of water supply and as climatic indicators.

4. The mapping, monitoring and prediction of those usage and polution aspects proved feasible, eg, rainfall, salt water content, sedimentation.

E. Oceanography and Marine Technology

Feasibility and Research Phase:

1. Identification and delineation of ocean currents (offshore and littoral), biological communities, refraction patterns from shoaling waves and breaking surf, sea ice, etc., based upon spectral characteristics of sea water.

2. Delineation of river effluent discharge patterns, shallow water sediment migrations, bottom topography, beach erosion and shoreline changes.

3. Examination of relationship between seasonal/climatic changes and sea surface state for use in meteorologic and oceanographic forecasting.

Operational Phase:

1. To survey the world's oceans on a largescale and continuous basis. To identify number and size of fish schools, and their movement and migration patterns so as to assist the fishing industry in supplying food for the world's population.

2. To monitor and chart the distribution and movement of sea ice and icebergs for the benefit of mariners.

3. To monitor and record such other oceanographic phenomena as may be proven feasible and desirable.

II. Capabilities

NASA is planning to use a manned satellite -- the APOLLO -- as the vehicle for its multi-spectral photographic observation program. This satellite system, operating at 150 n. m. altitude, has the capability to produce 147 million square miles of photographic product per mission. Setting aside the cost of such a mission (which will be considered later), the political desirability of an aggressive satellite overflight program, and the actual necessity or practicality of producing data at a rate orders of magnitude beyond the national interpretation capability, it is still reasonable to ask if a manned satellite is the best; i.e., most efficient, carrier. Certainly, some consideration should be given to unmanned satellites and to aircraft as vehicles competitive to APOLLO.

The U-2R aircraft operates at 65,000 feet producing a 70 n. m. swath over an 1800 n. m. flight line. Its coverage of 126,000 sq mi per mission can be acquired at resolutions as low as 1 meter. The U-2's flexibility makes it very adaptable as an observation vehicle; it can follow a complex non-linear flight path and also take advantage of changing weather patterns to deliver data in an operationally efficient manner. While the U-2 is severely limited in its ability to cover vast areas (say a hemisphere) in a short time period (a few days), it is a formidable contender for the task of covering large nations in a reasonable time period. For example, a single U-2 can cover all of Canada (disregarding weather) in 31 flights, or, stated in more reasonable operational terms, six U-2's could cover Canada in about five flights each. In the case of India, one U-2 could acquire total coverage in eleven flights.

The following outlines indicate the capability by objective area of APOLLO, unmanned satellites, and the U-2R to produce data for the NASA multi-spectral photographic experiment (cost, international politics, availability, and desirability are ignored):

A. Agriculture and Forestry

Objective	APOLLO	Unmanned Satellites	U2R
Topography	X	X	X
Timberline	X	X	X
Waterline	X	X	X
Snowline	X	X	X
Desertline	X	X	X
Grassland-Bushland Interface	X	X	X
Bushland-Timberland Interface	X	X	X
Grassland-Timberland Interface	X	X	X
Vegetation Density	X	X	X
Irrigation Water (Snow Pack)	X	X	X
Fields (less than 1 Acre)			X
Fields (One to Ten Acres)			X
Fields (Greater than Ten Acres)	X	X	X
Damage Assessment (Flood)	X	X	X
Livestock Census (Ecology)			X

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B. Geography and Cartography

	APOLLO	Unmanned Satellites	U2R
Land Use	X	X	X ✓
Urban Studies	X	X	X ✓
Transportation and Linkages	X	X	X ✓
Settlement and Population Movements	X	X ✓	
Resources Utilization	X	X	X ✓
Vegetation Cover & Soils	X	X	X ✓
Climatic Conditions	X	X ✓	LIM
Energy Budget (inc. water)	X	X ✓	
Geomorphology	X	X ✓	
Glaciology & Permafrost	X	X ✓	
Topographic & Thematic Mapping	X	X ✓	X

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C. Geology

	APOLLO	Unmanned Satellites	U2R
Rock Types (Gross)	X	X ✓	X
Lithology	LIM	LIM	X ✓
Porosity			X ✓
Permeability			X ✓
Fabric (Gross)	X	X ✓	X
Faults, Folds	X	X ✓	LIM
Salt Domes	X	X ✓	X
Coral Reefs	X	X	X ✓
River Effluents	LIM	LIM	X ✓
Stream Lake and Bay Deposits	LIM	LIM	X ✓
Dunes	X	X ✓	X
Intrusive Rocks	X	X ✓	X
Metallogenic Provinces	X	X ✓	LIM
Oil Shale	LIM	LIM	LIM
Surface Roughness	LIM	LIM	X ✓
Compaction	LIM	LIM	LIM ✓
Earthquake Zones	X	X	X ✓
Volcanos, Thermal Waters	X	X	X ✓
Heat Balance, Variations	LIM	LIM	LIM ✓
Glaciation (Continental, Valley)	X	X ✓	X

D. Hydrology

	APOLLO	Unmanned Satellites	U2R
Evapotranspiration	X	X	X
Rain Distribution & Infiltration	LIM	LIM	LIM
Ground Water Discharge	X	X	X
Subaqueous Feature Identification	LIM	LIM	LIM
Salt Content & Light Absorption of Water	LIM	LIM	LIM
Water Pollution	LIM	LIM	X
Reservoir Sedimentation	LIM	LIM	X
Effluents of Major Rivers	LIM	LIM	X
Runoff & Water Retention in Drainage Basins	LIM	LIM	X
Erosion & Sedimentation Rates	LIM	LIM	LIM

E. Oceanography and Marine Technology

	APOLLO	Unmanned Satellites	U2R
Sea Surface Thermal Mapping	X	X ✓	LIM
Currents	X	X ✓	LIM
Ice Surveillance	X	X ✓	LIM
Coastal Marine Processes	X	X	X ✓
Biological Phenomena	X	X ✓	X
Water Color Analysis	X	X ✓	X
Volcanic Activity	X	X	X ✓

It is clear from these tables that unmanned satellites and U-2 aircraft are directly competitive with APOLLO in meeting the NASA program, as outlined. The red checks, indicating the most effective sensor platform for each category of observation, reflect strong U-2 potential for meeting the majority of the needs.

In carrying out the NASA program satellites would be the superior vehicle whenever (1) very large areas -- such as the Sino-Soviet territory -- are to be surveyed on a total coverage basis, or (2) the data must be delivered on a synoptic (or near-synoptic) basis. There is no reason, even in massive undertakings, for the satellites to be manned. This fact is reflected positively in NASA's own document, "Proposal for a Multiband Synoptic Photographic Experiment for Manned Earth Orbital Missions," dated March 18, 1966, which says that the camera system "will require a minimum of attention since the operation will be pre-programmed" (p. II-8) and "the camera shall be fully automatic and pre-programmed to the fullest extent possible but shall also have provisions for manual over-ride" (p. III-1).

Aircraft would be a superior vehicle whenever the area to be covered in toto is on the order of Canada, India, or the United States, whenever the coverage is to be selective, or whenever a reasonable time period (say a week) may be devoted to the task.

III. Political Considerations

It is very unlikely that NASA will be permitted to conduct satellite overflights of denied territory within the foreseeable future. National and international pressures will discourage such flights, especially since they would of necessity be made on an "open" (announced) basis with free disclosure of flight results to the scientific community. A sizable portion of the data which NASA proposes to collect over foreign countries would be identified correctly by those nations as economic intelligence, and NASA's expectation that the sovereign nations of the world will sanction such surveillance is surprisingly naive.

In spite of its announced desire to "go global," NASA will undoubtedly find itself constrained to (1) observing only those countries which express a desire for observation (few and far between) or (2) conducting covert observation. Only the first option is compatible with NASA's peaceful image and functional franchise; it is logical to expect that, at best, NASA will be required to concentrate its economic surveillance on the United States and a few other volunteering nations. In meeting this constricted objective, the airplane becomes vastly superior to satellites in a majority of cases. The airplane has the further advantage of being an "honest" observation device, i.e., an aircraft taking pictures of India is observing only India, while a satellite photographing India may be (and can always be accused of) continuing its observations over Pakistan, China, the USSR, or any place else in the world.

IV. Economic Considerations

The APOLLO is the most expensive vehicle available as a carrier for the multi-spectral photographic program. Based on a buy and launching of eight per year, each launching costs $95 to $110 million. The costs divide as follows:

Command and service module	43.0
Lab module	10.0
SATURN 1B	23.0 to 37.0
Support, checkout, launching	20.0

Once flown the APOLLO is, of course, totally expended. The comparatively large amount of coverage obtained (147 million square miles) is a mixed blessing in that the national interpretation capability is saturated by the accession of ·ne-tenth that amount.

Unmanned satellites are much less expensive ($9.0 million for a KH-4 and $10.0 million for a KH-7) and are capable of performing at a level which more than meets the objectives of the NASA program. Their lifetime on orbit is not nearly that of an APOLLO but it is not clear why a 45-day lifetime should be critical to the program.

U-2's are $2.7 each (in the "R" version SR-71's cost $15 million each; 36 U-2R's could be purchased for the cost of one APOLLO mission. They have the advantage of being re-usable and of being very useful in the military inventory whenever their civil mission would be completed.

V. Summary

It is clear that U-2R aircraft and unmanned satellites are directly competitive with APOLLO in meeting the NASA program objectives.

The U-2R is the superior sensing platform whenever one considers the area to be covered to be on the order of Canada, India or the U. S.; whenever the coverage is selective; or whenever a reasonable time period is permitted for the task.

A satellite would be the superior vehicle whenever very large areas -- e. g., the Sino Soviet territory -- are to be surveyed on a total coverage basis or whenever the data must be delivered on a synoptic basis.

This is not to say that the satellite need be APOLLO. Factually, there is no reason, in even massive undertakings, for the satellite to be manned.

Politically, it is highly unlikely that NASA will be permitted to conduct satellite overflights of denied territory within the foreseeable future.

NASA will undoubtedly find itself constrained to observing only those countries which express a desire for observation or to conducting covert observation.

In meeting this constricted objective, the airplane becomes vastly superior to satellites in a majority of cases and has the further advantage of being an "honest" observation device.

APOLLO is the most expensive vehicle available as a carrier for the NASA multi-spectral photographic experiment, costing approximately $100 million per launch. Unmanned satellites are much less expensive -- approximately $9 million per launch and are capable of performing at a level which would more than meet the NASA program objectives: U2R's cost $2.7 million each; SR-71's cost $15 million each. Both have the advantage of being reusable and useful in a follow-on military requirement.

Camera/Vehicle Comparison

	APOLLO	U-2R	SR-71	
	Multiband Synoptic	B Camera	Operational Objective Camera	Terrain Objective Camera
No. of cameras	4	1	2	1
Type of camera	Frame	Frame	Pan	Frame
Film size	5"	2-9"	70 mm	9.5"
Focal length	3"	36"	13"	6"
f number	6	5.6	3.5	5.6
Ground resolution*	60M	1M	.5M	5M
Angular coverage	74°	142°	87°	74°
Swath width	225 nm	70 nm	26 nm	21 nm
Linear coverage**	655,000	1800	3978	7544
Area coverage	147M sq mi	126K sq mi	104K sq mi	159K sq mi
Camera weight	250#	375#	285#	120#
Vehicle				
Range	-	7200 nm	14,000 nm	14,000 nm
Speed	-	460 kts	3.2	3.2
Altitude	150 mi	65,000'	85,000'	85,000'
No. flights to cover: CANADA 3,851,809 sq mi	1	31	38	25
No. flights to cover: INDIA 1,269,835 sq mi	1	11	13	8

* APOLLO resolution degraded from report by factor of 3 for earth orbit mission at 150 miles

** With 55% overlap.

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Area Photo Coverage by U-2R

Basis:

Time Period	30 Days
Assigned	20 Aircraft (1 Squadron)
Utilization Rate	35 Hours/ Acft/Month
Sortie Rate	3 Per Aircraft/Month
Sortie Duration	7 Hours Average
Camera	36" Focal Length "B"
	5' Ground Resolution
	1800 n. m. Linear Cover X
	70 n. m. Swath
	126,000 sq miles cover per sortie

Costs:

Initial Cost 20 Acft *	$48,008,000
30 J-75-13B Engines	9,600,000
	$57,608,000

O & M:	POL	$ 44/Hour
	Maintenance	82/Hour
	Spares	84/Hour
		$210/Hour

* Eleven (11) "B" cameras available from SAC

O & M for Squadron (Total)	$147,000/Month
O & M for Ops Coverage	88,200/Month

SUMMARY:

20 U-2R aircraft, flying 60 sorties, can photograph 7.5 million square miles (5' ground resolution) at an initial cost of $57.6 million, plus a total monthly O & M expense of $147 K ($88,200 of this figure is for ops O & M).