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VOYAGER IMAGING SCIENCE INVESTIGATIONS

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ABSTRACT

The Voyager Imaging Science Experiment objectives at Saturn include exploratory reconnaissance of Saturn, its satellites and its rings. The imaging cameras are described, along with an abbreviated discussion of specific objectives.

At the time of the NASA/JPL Saturn's Ring Workshop in 1973, I presented a description of the Mariner Jupiter/Saturn imaging experiment. Significant changes have taken place since that time: the Imaging Science Subsystem has evolved into one much better suited to meet the scientific objectives of the investigation, and the project has changed its name. Recently, the Voyager Imaging Science Team published a moderately detailed description of both the instrument and the scientific investigation (Smith *et al.*, 1977).

Figure 1 is a schematic representation of the medium resolution and high resolution cameras being flown on the two Voyager spacecraft. For reasons of historical significance only, these cameras are referred to as the "wide angle" and "narrow angle" cameras, respectively. The focal length of the wide angle camera is 200 mm, and the narrow angle camera is 1500 mm. Each camera employs a selenium-sulfur, slow-scan vidicon which provides an 800 × 800 array of 14-μm pixels, each digitized to 8 bits (256 levels of gray). The fields of view are 3°2 and 0°4. Additional camera characteristics are shown in Table 1.

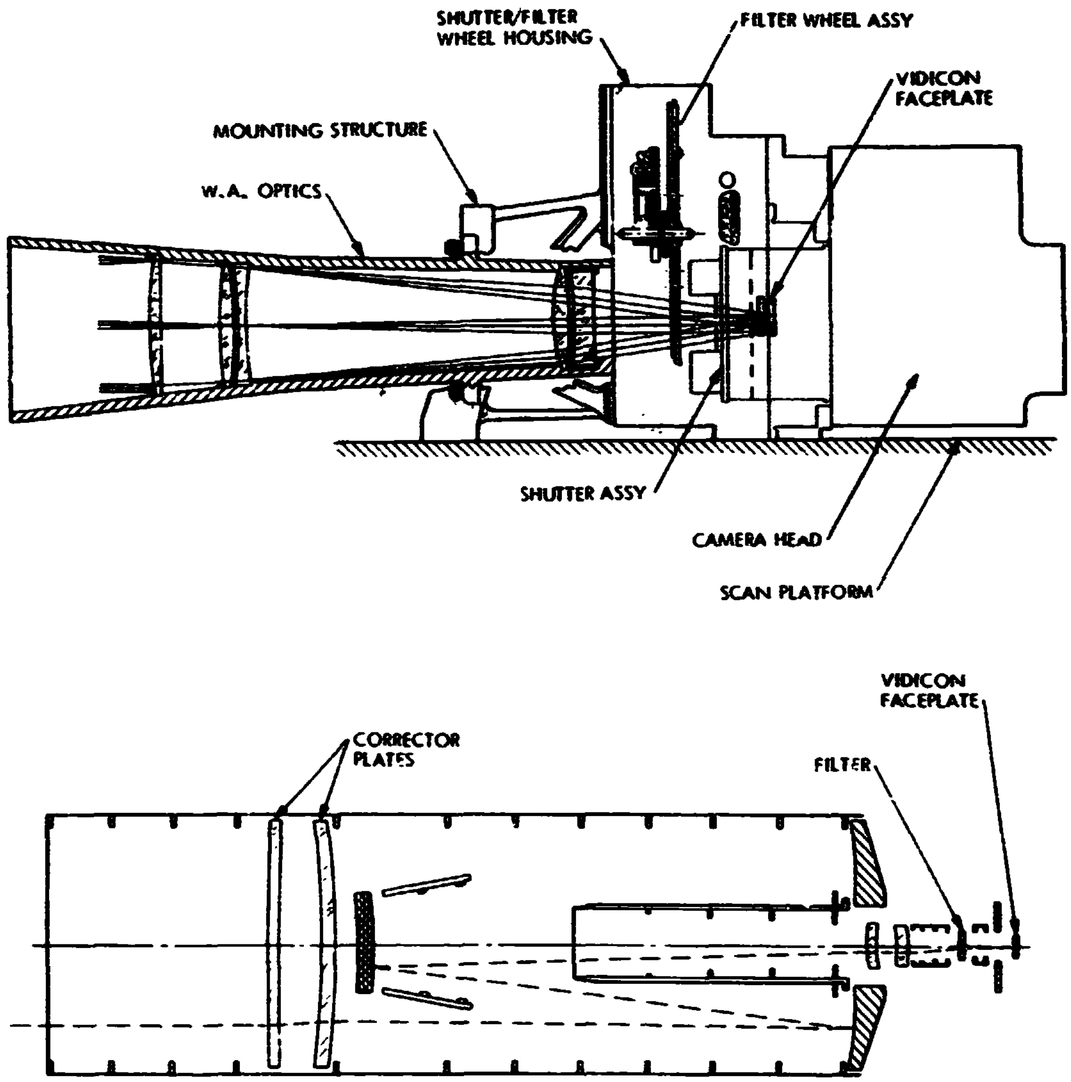

Figure 1. Imaging Experiment - Schematic Representation of the "Wide angle" and "narrow angle" Cameras for Voyager

Table 1. Imaging Science Subsystem Characteristics

Characteristic	Narrow angle camera	Wide angle camera
Focal length	1499.125 mm[a]	201.568 mm[a]
Focal number	F/8.5[a]	F/3.5[a]
Field-of-view	7.5 7.5 mrad	55.6 55.6 mrad
T/Number[b]	T/11.83[a]	T/4.17[a]
Nominal Shutter operation	0.05 to 15.36 sec	0.005 to 15.36 sec
Active Vidicon Raster	11.14 11.14 mm	11.14 11.14 mm
Scan lines per frame	800	800
Picture elements per line	800	800
Pixels per frame	640 000	640 000
Bits per pixel	8	8
Bits per frame	5 120 000	5 120 000
Nominal frame times	48 to 480 sec	48 to 480 sec
Video baseband	7.2 kHz	7.2 kHz
Video sampling frequency	14.4 kHz	14.4 kHz
Angle subtended by scan line	9.25 rad	69.4 rad
Nyquist Frequency	32 line pairs/mm	32 line pairs/mm
Resolution 10% Modulation at	36 line pairs/mm	36 line pairs/mm

[a] Actual data from prototype camera systems.

[b] T/Number – An effective F/number which includes obscuration and transmission losses.

Each camera has eight filters which cover a spectral range from 425 to 600 nm in the wide angle camera, and from 345 to 590 nm in the narrow angle camera. In addition, the wide angle camera has three narrow-band filters centered on the methane absorption bands at 541 and 619 nm, and on the sodium D_2 line at 589 nm.

Observational sequences for Saturn have not yet been developed, and there remains unanswered some crucial questions relating both to telemetry performance and to on-board, data-storage management throughout the Saturn encounter. Thus, it is not presently possible to discuss observational objectives and the sequences necessary to achieve them with the same degree of detail that I could now give for Jupiter. However, it is clear that telemetry rates will be lower at Saturn than at Jupiter and that inter-experiment sequencing conflicts will be much more serious. In other words, lower telemetry rates mean less information, no matter how clever we become in developing our observational sequences.

Arrival times at Saturn are 13 November 1980 for Voyager 1 and 27 August 1981 for Voyager 2. In the baseline plan we will begin imaging in the "observatory" phase 80 days before each encounter; that is, late August 1980 and early June 1981, respectively. At that time we will be a little less than 100 million km from Saturn and the resolution of our narrow angle cameras will be approximately 2000 km per line pair. This is about twice as good as the very best photographs taken from the Earth. Throughout the observatory phase resolution tends to increase linearly with time, reaching 2 to 3 km/lp on the disk of Saturn at the time of encounter. The best resolution on the rings may be a little higher still, but will eventually be limited by image smear caused by the motion of the spacecraft.

Scientific investigations of the satellites of Saturn will include distant imaging of the entire satellite system and near-encounter high resolution imaging of several satellites. At least some near-encounter imaging will be obtained over sub-hemispheric areas on all of the inner satellites: 3 km or better on Mimas, Enceladus, Tethys, Rhea, Dione, and Titan with 1 km or better on Mimas, Rhea, and Titan. Hyperion and Iapetus will be seen with resolutions of 10 to 20 km. The total attainable coverage of the surfaces of these satellites will be determined by actual data rates, sequencing conflicts and, to some extent, by image smear.

The following are among the scientific objectives to be pursued by the satellite subgroup within the Imaging Science Team:

Size and Shape: The sizes and shapes of most of the satellites will be determined with uncertainties between 0.1 and 1.0 percent.

Global High-Resolution Mapping: Between 20 and 40% of the illuminated hemispheres will be photographed in several colors. In some cases, the two spacecraft trajectories will provide balanced polar and equatorial coverage. These high-resolution observations will be used to examine the fine-scale details of major physiographic provinces and the nature of the transition regions.

Polar Volatiles: The polar regions will be explored for deposits and structures related to the past histories of these surfaces, including studies of the morphologies and interrelations of possible ice-related features. With equatorial-noon and polar temperatures ranging from ~100 K to ~30 K, stable ices should include water, certain sulfides, ammonia, and ammonium hydrates (Lebofsky, 1975). The polar regions, being at all times colder than other areas, may have acted as sinks for volatile materials originating elsewhere. These regions are, therefore, of special interest.

Titan: There is a lack of consensus in our understanding of Titan, and carefully planned spacecraft measurements are required if we hope to resolve these issues. The diameter and figure are the first priority. The next step is to establish whether this observation refers to the surface, or to a haze in a dense, molecular atmosphere, or to a uniform cloud layer. This might be accomplished by imaging observations in several colors. The suggestions that Titan may possess clouds, aerosols or even dust layers requires that it possesses weather systems. Titan is a slowly rotating planetary body with an orbital period of about 16 days, and thus, the circulation of the satellite atmosphere could represent an intermediate case between the baroclinic circulation typical of the mid latitudes of the earth and Mars and the symmetric Venus weather patterns.

In addition to the study of each satellite as an individual planetary body, we will, of course, pursue an intercomparison among all observed satellites in the Saturn system, and with those in the Jupiter system as well.

The Voyager mission provides a unique opportunity for the study of atmospheric systems very different from our own. At both Jupiter and Saturn, Voyager will achieve higher resolution and a longer observing time base than that obtained by Pioneer; both resolution and time are improved by a factor of about 50.

Throughout the observatory phase the disk of Saturn will be photographed in at least two colors (orange and ultraviolet) at five equally spaced longitudes during each rotation. Approximately three weeks before planetary encounter, the disk of Saturn will exceed the field of view of the narrow angle camera and mosaicking will be necessary. The extent to which global coverage with 2 × 2 and 3 × 3 mosaics can be maintained will depend upon data rates and tape recorder use. Eventually we will have to terminate this full disk coverage and concentrate on features of special interest identified and selected during the observatory phase.

During the observatory phase, observations in both space and time will provide information on the synoptic development, growth, and dissipation of atmospheric systems, and will provide the first opportunity to observe the zonal velocity field at the cloud tops. Unlike Jupiter, Saturn as seen from the Earth presents a dearth of non-axisymmetric features necessary to measure zonal wind components. In fact, only 9 such features have ever been observed, leaving unknown the zonal velocities associated with most of the planet's axisymmetric structure.

The near encounter observational sequences of Saturn will be nearly identical to those carried out at Jupiter, in that a major objective of the Voyager mission involves a detailed comparison of the meteorologies of these two planetary atmospheres As an example, the Pioneer 11 observations of Gehrels *et al.* (1974) show that the axisymmetric structure terminates on Jupiter approximately 45° from the equator. The Voyager spacecraft trajectories, however, require the Jovian encounters to take place nearly in the equatorial plane, so that it will not be possible to make highest resolution observations of the Jovian polar regions. We do not yet know whether this transition also occurs in the Saturn atmosphere and, if so, at what latitudes. Fortunately, the Voyager trajectories make it possible to observe both the north and south poles of Saturn (see Figure 2) to complete the comparison of the Jovian and Saturnian meteorologies.

There are several types of observations of Saturn's Rings to be made with the wide and narrow angle cameras, which should yield information on the photometric properties of the particles and predicted radial drift displacements of particles within the rings. General profiles of the rings in reflection obtained during the observatory phase at nearly uniform phase angle may be used to interpret those obtained during encounter, when phase angle will vary greatly across the profile.

Strip sequences of images with high resolution taken across the rings will give information about minor divisions. If the strip is timed and placed so as to see the

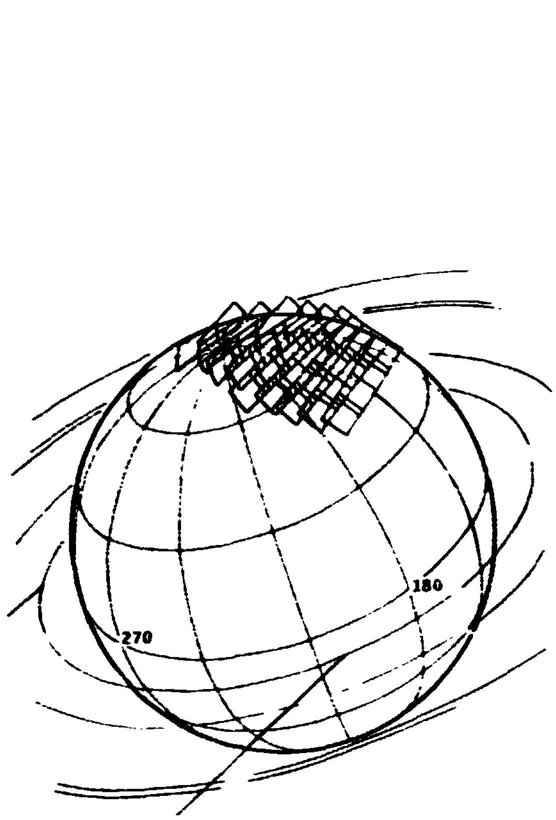

Figure 2. Typical Saturn Pole Coverage

turned-up illuminated outer edge of an inclination resonance as predicted by dynamical theory (Cook, 1978), a useful check on that theory will be obtained. If minor divisions are seen, we can establish lower limits on drift displacements across the corresponding resonances. The width of a division gives us the distance of drift during the age of the rings. Invisibility of a division gives us an upper limit on the distance of the drift or implies that the collision frequencies between particles are too high to allow the resonance to develop.

The existence of Ring D should be settled once and for all, and excellent profiles of Ring C and Cassini's Division will be obtained.

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DISCUSSION

D. MORRISON: You talked about weather and clouds on Titan in a way that made me think you expected to see cloud patterns. Doesn't the large optical depth of haze suggest it would be more like looking down on Los Angeles on a smoggy day, where you see nothing?

B. SMITH: Yes. Although, if there are clouds above the haze, we'll see them.

J. POLLACK: I don't think we have good numbers for the optical depth of dust or haze on Titan right now. From that point of view I'd be a little hesitant to say we won't see exciting atmospheric features on Titan.

J. CUZZI: From what George Siscoe was saying about the sputtering going on at the outer edges of the rings, it would be especially interesting to look at the outer edge of the A ring.

G. ORTON: Do you have any filters that are located in the methane red bands?

B. SMITH: Yes. The 619 nm methane absorption band, and the band at 541 nm. The 541 nm filter was put on for Uranus. There is no hope of seeing that band on Saturn.

D. MORRISON: Is there any problem with scattered light for features like the D Ring or the inside of the Cassini division? Are you confident that your system has low enough scattered light levels, and that you will be close enough, to see into these regions?

B. SMITH: Absolutely confident.