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Apr 1st, 8:00 AM

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THE PALAPA SPACE COMMUNICATION SYSTEM

Staying In The Space Communication Business In An Uncertain STS World

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ABSTRACT

Indonesian social development has depended greatly upon the PALAPA space communication system since 1976 as one major component in the creation of a national infrastructure to enhance business development and the dissemination of national cultural information. The success of the first two satellites in serving telephone and television and in serving the Asean region has made it necessary to assure the continuity of these operations through the 1980's and beyond. Replacement B1 and B2 satellites have been contracted for delivery in early 1983. The uncertainties of placing these two new satellites in their chosen geosynchronous orbit locations has presented some unique problems of management particularly in respect to the choice of launch vehicles due to launch uncertainties, and the assessment of the risk of potential launch failure on ongoing telecommunication system operations. Planning for recovery from the many contingencies presented as potential catastophies in the path to successful replenishment of the present space system has necessitated consideration of a number of strategies involving launch schedule for alternate vehicles, launch insurance, relaunch costs, as well as component production delays and launch slot availability for space flight operations.The objective of these management considerations have been to minimize costs to the Indonesian government while providing a high degree of assurance that the required communication capacity of the satellite system will be maintained in support of the national telecommunication system.

INDONESIAN SOCIAL OBJECTIVES

Indonesia is a dynamically growing country with a population of over 130 million inhabitants distributed in 50 thousand villages and cities throughout a land area of about 1.9 million square km. This population is distributed among 992 inhabited islands. The social organization of the country and its government has evolved around a policy of equitable distribution of new development benefits among the population in order to improve the standard of living for all. National five year development plans (REPELITAS) have been the motivating force in the creation of a balanced infrastructure (roads, power distribution and telecommunications) in support of agriculture, mining, manufacturing and commerce. These development plans have as their major objective the attainment of the "TRILOGY OF DEVELOPMENT": a high rate of economic growth, equitable distribution of growth benefits to all, and the creation of social justice and stability of the society.

Telecommunications have played a major role in the implementation of the development policy of the country. The national telecommunication network consists of terrestrial networks, including local cable, a microwave system spanning the major island population centers, undersea cables linking on major islands, and the PALAPA satellite communication system.

The major development of the national telecommunication system began with the advent of the first REPELITA in April 1969. This included the aquisition of the Java - Bali microwave system and its extension to Sumatra island. The second REPELITA laid the plans for the further development of the microwave system, improvement of local services and the preparation of plans for introduction of the PALAPA system. PALAPA was inaugurated on August 16, 1976. The introduction of PALAPA A1 made it possible to provide improved telephone and telex services among forty earth station locations which were integrated into the national telecommunication network. At the same time TV distribution was provided and served an increasing number of locations which broadcast, locally, the transmissions of the Jakarta uplink. The system also provided a live demonstration of teleconferencing using as the second TV uplink the main traffic station at Banda Aceh. The success of PALAPA during REPELITA II has permitted the further evolution of plans, during the current REPELITA III, for the further pursuit of more ambitious programs under the TRILOGY OF DEVELOPMENT: agriculture, industry, employment, population redistribution, regional development, improvement of health and educational services and upgrading of the environment. Telecommunications as part of the continuing development of infrastructure has continued to receive a high priority for support from the government.

Within the national telecommunication network PALAPA has played an increasingly important role in bringing telephone services to many remote or isolated communities within the Indonesian archipelago's many islands. The system has grown from the initial forty earth stations to a projected 228 operating earth station during 1982. Almost all of these will provide for TV reception in addition to telephone and telex service using SCPC with demand or fixed frequency assignments for operation with the existing satellite system. The satellite system has, in a large measure, been found to be a very economical means of serving many locations well before new terrestrial transmission facilities could be introduced in the same locations. For this reason Indonesia has placed a great deal of reliance upon the satellite systems and has planned for their replacement with the new twenty four channel PALAPA B systems which are now being built by Hughes for launch in 1983 and 1984. Some of the management problems, and related technical matters which have been encountered in bringing these new satellites into the national system are presented in the following sections.

TECHNOLOGY - FOR REGIONAL COMMUNICATIONS VIA SATELLITE

The PALAPA A-series satellites each provide twelve channels with a nominal bandwidth of 30 MHz, in a conventional 6/4 GHz transmission format. TWTAs provide 5 watts into an antenna which covers the ASEAN region with a minimum e.i.r.p. of 31 dBW and a G/T of - 7 dB/K. Geosynchronous orbit locations are 77° E. and 83° E. longitude. Transponder availability was initially projected to be 70 % of the TWT complement by the end of the seven years projected life of each satellite. The solar array was designed to provide 300 W of power and the battery system sized to be able to maintain full capability of the twelve TWTA's during eclipse operations.

As a regional satellite system PALAPA makes use of smaller earth station antennas than those usually employed by Intelsat. The control station and eighteen main traffic stations employ ten meter diameter antennas which provide a G/T of 31 dB/K. The remaining light traffic stations in the initial system also employ ten meter antennas but new stations to be used for light traffic service employ 4.5 to 5 m antennas. These new stations will provide a G/T of 22 dB/K. All of these smaller stations operate with SCPC terminals using 400 TWT amplifiers, and provide high quality TV for local rebroadcast.

The growth of the telephone service in Indonesia in the nine year period from 1969 to 1978 has been at an average rate of 33 % per year. Similarly, telex and subscriber long distance dialing have grown at substantially the same rates. Transponder utilization from initial operation in 1976 has grown from 7 transponders to a total of 13 1/2 in 1982. This represent a growth rate of 12 % per year. Transponder availability and utilization are shown in Figure 1, "PROJECTED SYSTEM CAPACITY FOR A1 AND A2 FOR THE PERIOD 1976 TO 1978". A predicted need for 20 transponders for the year 1983 is shown, together with the 1976 and 1982 actual transponders in use. Since operational planning for PALAPA includes maintenance of a number of spare channels for the A1 and A2 satellites, these figures showed a need for replenishing the system in 1983. This was further emphasized by the onset of expected system capacity losses shown by the shaded areas in Figure 1. Accordingly plans for the aquisition of PALAPA B1 and B2 were undertaken and a contract signed with Hughes on Dec 20, 1979. Negotiations for launch support were also concluded with NASA for optional STS or Delta Launch services for the two spacecraft on Dec 9, 1980.

The introduction of PALAPA B1 and B2 into the Indonesian system by 1983 and 1984, nevertheless, has created some concern for the continuity of operations, during the period for satellite construction and the uncertainty of launch schedules. In part the satellite characteristics were chosen as a result of growth predictions, and in part by recognition that if a failure of the first launch were to occur a second launch would be needed not only for growth, but for operations which would have to accomodate both A1 and A2 traffic, assuming these sateliites come to the end of their useful life during the years 1983 to 1986. A major concern, therefore, was the state of health of the A1 and A2 satellites, together with predictions of their useful life times over the period when a new PALAPA B could be made operational.

One of the first concerns then became: what can be done to provide continuity of communication service in the event of failures of A1 and A2 before a B satellite becomes operational? Three solutions suggest themselves:

1. Off-load some satellite traffic to the microwave backbone-system and retain traffic on the satellites that has no other means of transmission.

2. Improve the utilization of individual transponders by using more efficient ground systems, e.g. TDMA instead of FDM/FM.

3. Delay commissioning new earth stations until new transponders become available.

A second concern was the actual state of health of the two operational satellites. Three major subsystems were evaluated to assess their potential contributions to system degradation or loss.

REEVALUATION OF ON ORBIT LIFE OF TWTA'S

As of 1 February 1982 The PALAPA system has experienced no failures among the twenty four TWTA'S in operation. Predictions made by others, however, have indicated that some failures should have been experienced. The question raised, therefore, was: is PALAPA extremely lucky, or have these predictions been made correctly? It was decided to reexamine data available in the literature which provided time to failure of TWTA [Ref. R. Strauss and J.R. Owens: "PAST AND PRESENT INTELSAT TWTA LIFE PERFORMANCE"; AIAA Conference Record, 1980; pp 98 - 106]. These data were examined assuming that a log normal distribution of failure times could represent the observed data. The information available provided the times of failure for 24 TWTA'S from a total of 98 in orbit. These failed units represented two modes of on-orbit operations: continuous and eclipse on/off cycling. The on/off cycling is known to induce premature failures of the TWT's. Nevertheless both modes of operation were included in the new analysis of the data; the result are shown in Figure 2 "EMPIRICAL DISTRIBUTION OF TWTA FAILURE TIMES DURING ON-ORBIT OPERATIONS".

From this new distribution, it may be seen that the mean failure time (50% loss) is 11.77 years. If this distribution is representative of PALAPA, it becomes possible to predict a loss of three transponders at the end of the nominal seven year life span of each spacecraft.

This published Intelsat data would seem to indicate that at least 10 % of the operating TWTA'S should have failed on PALAPA by this time. The fact that no failures have been experienced tends to indicate that the data used are conservative, in that when eclipse cycled data are removed from consideration, better lifetimes than those now predicted would be projected. Based on these conservative data, projections have been made for PALAPA TWTA lifetimes, and are shown in Table 1 "PROJECTIONS OF TWTA LOSSES FOR ON-ORBIT OPERATIONS".

REEVALUATION OF ON-BOARD FUEL RESERVES

On board reserves have been monitored continuously throughout the operations of PALAPA A1 and A2. Starting whith 115.91 lbs of fuel, Sept 1976 and 117.20 lbs, July 1977, with consumption rates of 12.31 and 11.26 lbs/yr., respectively, it is estimated that fuel exhaustion will occur in February 1986 and December 1987.

POWER SUBSYSTEM PERFORMANCE

Solar array output has been monitored by measuring the output voltage under standard load current conditions needed to operate the twelve TWTA's and the other spacecraft subsystems. Degradation observed thus far in the in-orbit life of the spacecraft indicates that this subsystem could operate successfully for over ten years.

An examination of the battery subsystem in 1980 tests, similarly, has shown that the depth of discharge observed during a 1.15 hour eclipse period resulted in a depth of discharge of 59.8% and 56.5% in comparison to a 61.5% nominal design value DOD. Based on these values battery capacity appears to be adequate to meet full operational needs, but at this time there is insufficient data to make a reasonable prediction for battery degradation or life. Nevertheless, the battery subsystem is not expected to be a limiting factor in the system life.

The nominal seven year life span of the A1 and A2 satellites will be attained in July 1983 and March 1984. Present rates of degradation for the three key subsystems indicate that they will continue to operate well beyond the nominal life periods guaranteed by the space segment manufacturer. The status of these subsystems is summarized in Table 2, "PROJECTED SUBSYSTEM LIFE TIMES OF PALAPA A1 AND A2".

The introduction of the two PALAPA B satellites, with current launch dates of April 1983 and Jan 1984 will add to the existing Indonesian system capacity as shown in Figure 3. The two satellites, it may be seen, provide for the growth of the system, and for the replacement of the A1 and A2 satellites. With this plan, it was next necessary to arrange for the placement of the new satellite into their orbital slots. This posed a problem of launch vehicles selection, while at the same time providing some potential for cost savings, but introducing a great deal of uncertainty in mission success and launch scheduling.

UNCERTAINTY AND CONTINGENCY

The choice of launch vehicles in 1979 were Ariane, Delta and STS. Each of these have their advantages and disadvantages. Delta was a proven vehicle, but expensive. Ariane was unproved, but could be less expensive, if and when it became operational. STS was attractive in terms of price but was also unproved and subject to uncertainty of available launch date. This initial problem was resolved by selecting NASA as the launch agency and reserving both Delta and STS launches. This however required progress payments for two distinct launch programs. The choice of Delta was made to assure a launch at the selected launch date, while STS, it was hoped, would become available in time to meet the system operational dates required. This dual purchase of launch vehicles was continued until June 1981, when NASA was advised that PALAPA would be launched by STS since suitable space in the STS manifest was made available for PALAPA B1 and B2 satellites by NASA. With these plans firmly established the following remained to be resolved:

- The possibility of launch failure
- The need for suitable insurance
- The possible need for a backup satellite and Launch Vehicle.

The possibiltiy of launch failure led to an examination of the impact of on-orbit transponder availability. A scenario was developed to provide a guide in analyzing the effects of launch failures and provide the information needed to meet any contingency in the program. It was recognized that the probability of a launch failure was small, and that the loss of both B1 and B2 was not very likely. The launch failure models used therefore were:

- PALAPA B1 fails and B2 succeeds
- PALAPA B1 succeeds and and PALAPA B2 fails.

Naturally, with B1 and B2 successes there would be no need to consider a back up satellite or launch vehicle.

The impact on transponder availability of these two launch failure modes is shown in Figure 4 and Figure 5.

From the launch failure models it may be seen that, to cover a potential loss of system capacity, it would be necessary to plan a launch during the period May 1983 to January 1984. A Delta launch in June 1983 would be available if ordered before January 15, 1982. This launch, if not needed, would still be available for backup of B2, in the event of a loss of B1. None of the available STS manifest slots are available during the period May 1983, Jan 1984. This situation however, may improve over the next year. For the purpose of planning back-up launches the following constraints need to be taken into consideration, assuming that the best available choice will be made using either DELTA or STS launch opportunities:

A. <u>DELTA CONSTRAINTS</u>:

A short term start up for a Delta launch was available prior to 15 January 1982. The Delta would have been available either for B1 or B2 operations. Thus launches in either March 1983 or June 1983 could be selected. This option was not accepted. Delta procurement normally requires 30 months for delivery.

B. <u>STS Constraints</u>:

Opportunities which appear to be available from the present STS manifest are as follows:

1. July 1984, flight 17/99
2. July 1984, flight 18/103
3. Febr. 1986, flight 40/99
4. Dec. 1986, flight 52/99.

These uncertainties of launch operations have an impact on the cost of the system operation by a need for:

- Insurance on the assetts at risk and third party liability.
- The construction of a satellite and launch vehicles and securing launch services to meet contingencies.

Indonesia has elected to cover this entire range of uncertainties through a single insurance policy. This document provides not only for the loss of the equipment but also covers the costs for relaunch of failed missions.

Preparing the insurance policy to cover the entire range of risks, has , in itself, been a problem of no small magnitude. The issue to be dealt with is the uncertainty of a launch opportunity for a failed mission.

The uncertainties of space operations and of possible relaunch costs lead to the question of how this may be covered by appropriate insurance. To solve this problem, Indonesia has planned to include in its insurance policy the possibility of a relaunch by Delta if a suitably timed STS relaunch was not available.

This need is based on the assumption in the case of a non-NASA related failure, that:

- a suitable STS reflight could not be guaranteed, due to a crowded manifest
- a suitably timed Delta launch would be feasible.

In view of the difficulties in obtaining a replacement satellite for a suitably timed launch, it may be necessary to consider ordering these equipments and services prior to the actual loss.

This would mean additional cost even though the impact of such cost is not as serious as the loss of services in the event that it is not possible to get a replacement satellite in place before the loss of capacity of the existing system. These decisions are also complicated by the crowded launch schedules which limit the user's ability to make plans which are more responsive to his system needs. This situation is acute for contingency operation and merit the attention of users who have to keep their space systems in operation and of NASA as the supplier of launch services.

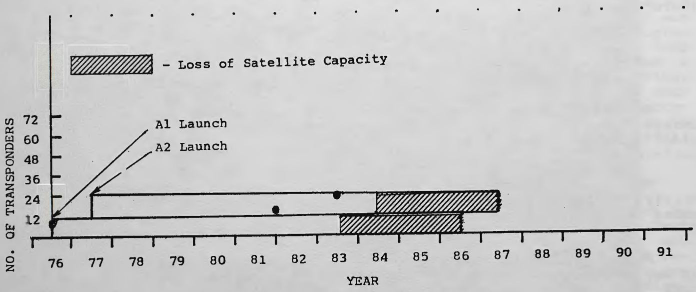

FIGURE - 1
PROJECTED SYSTEM CAPACITY FOR PALAPA A1 AND A2 SATELLITES FOR THE PERIOD 1976 TO 1987

TABLE 1.

PROJECTION OF TWTA LOSSES
FOR ON-ORBIT OPERATIONS

-SINGLE SATELLITE-

Years	Months	10 Log (mo)	% Loss	No of Lost TRANSPONDERS
6	72	18.57	16	2
7	84	19.24	23	3
8	96	19.82	29	3 - 4
9	108	20.33	35.5	4 - 5
10	120	20.79	41	5
11.77	141.24	21.50	50	6

TABLE 2
PROJECTED SUBSYSTEM LIFETIMES
OF PALAPA A1 AND A2

Satellite	Launch Date	No. of TWTA'S	On Orbit Time * (yrs)	TWTA Avail*	Est. Fuel Reserve Time#	Battery Voltage Time#	MIN TWTA Avail Time#
A1	July'76	12	5.50	12	Feb' 86	Not	July 84
A2	March'77	12	4.75	12	Dec' 87	known	March85

* January 1. 1982 # Projected - Jan 1, 1982 - for 10 TWTA'S operational.

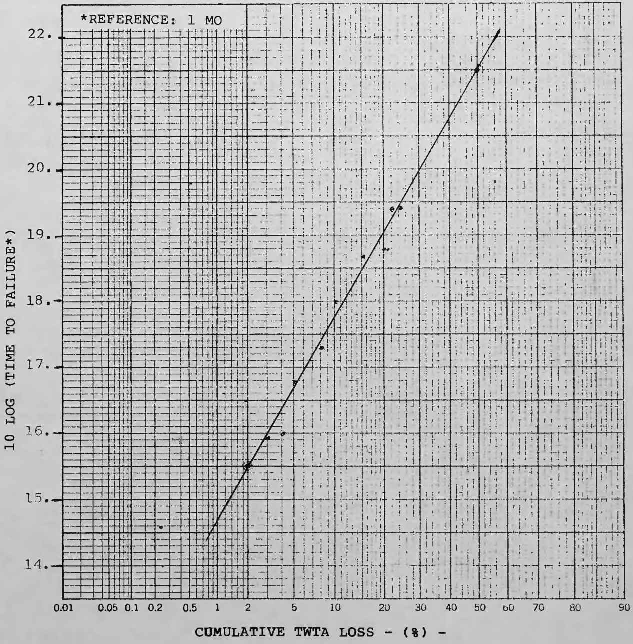

FIGURE - 2
EMPIRICAL DISTRIBUTION OF TWTA
FAILURE TIMES DURING
ON - ORBIT OPERATIONS

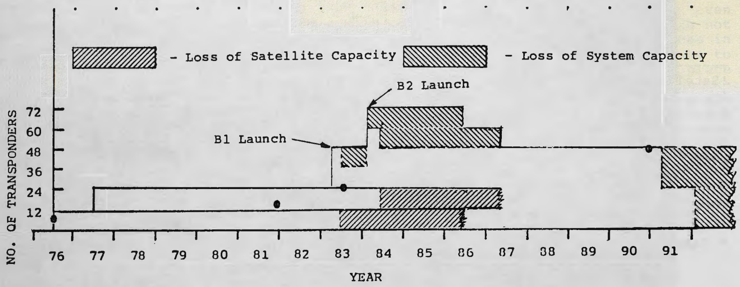

FIGURE - 3

TRANSPONDER AVAILABILITY - DESIGN TARGETS FOR FULL SYSTEM OPERATION

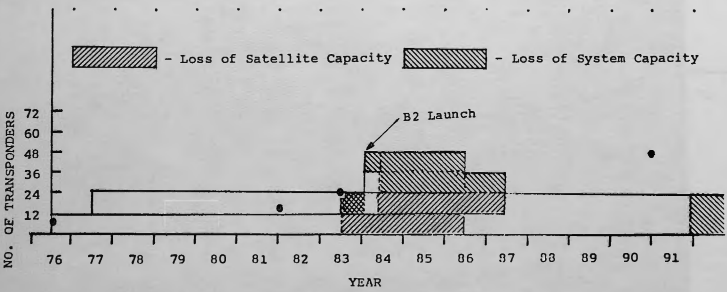

FIGURE - 4

TRANSPONDER AVAILABILITY - FAILURE SCENARIO ONE
LOSS OF B1, SUCCESS OF B2

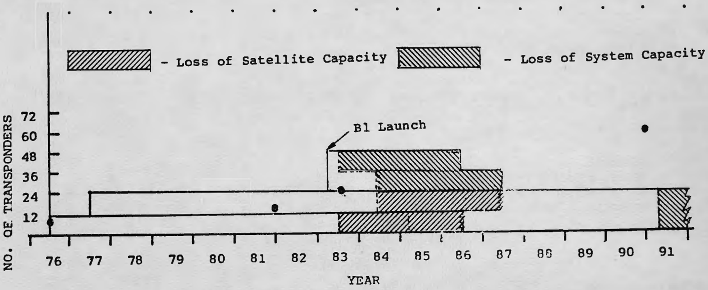

FIGURE - 5
TRANSPONDER AVAILABILITY - FAILURE SCENARIO TWO
SUCCESS OF B1, LOSS OF B2