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ADDENDUM

TO

DEVELOPMENT CONCEPT PAPER (4 September 1973)

DEFENSE NAVIGATION SATELLITE DEVELOPMENT PROGRAM

21 September 1973

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I. Scope: This addendum describes an additional alternative for a Defense Navigation Satellite Development Program (DNSDP). A description of the technical aspects of Alternative IV and a comparison of this alternative with the three discussed in the 4 September 1973 Development Concept Paper are presented. An updated schedule for each alternative is included.

II. Alternative IV: This alternative describes the first phase of an evolutionary, decision-based development effort leading to an operational Defense Navigation Satellite System. Phase I emphasizes development, test and evaluation (DT&E) of user equipment. Phase II completes the initial operational test and evaluation (IOT&E) of user equipment and leads to an early, limited operational capability. Phase III will develop the full operational capability of the DNSS.

A. During Phase I, two generalized development models of user equipment will be designed, fabricated, and tested. These generalized models will have the capability to functionally simulate any one of six user equipment classes. Thus, they will be test beds to investigate and evaluate alternate design concepts. These concepts will incorporate a high degree of subassembly commonality among the various classes of user equipment by the use of modular designs. During this phase, sufficient quantities of Advanced Development Units, or development models, will be procured to support comprehensive DT&E. (See Table A-1). This is the first of three design-test-design cycles to determine preferred user equipment designs and validate life cycle cost models. As each class of user equipment completes DT&E, Engineering Development Units, or prototype models, will be fabricated and enter into Initial Operational Test and Evaluation (IOT&E). By the end of Phase I, prototypes of the low cost user equipment class will have started IOT&E, more sophisticated classes of equipment will have completed DT&E, and the man back-pack class, due to unique miniaturization and packaging requirements, will be ready for procurement of development models for DT&E.

The satellites to be launched during this phase will be used to further operational system technology, be phased with and support the testing of user equipment, be prototypes of satellites to be procured in later phases of the program, and contribute to the limited operational capability in Phase II. The Joint Program Office (JPO), through the Navy (PME-106), will launch two Navigation Technology Satellites (NTS). NTS-1 will investigate stable clock technology and provide initial space-based testing of navigation signals. (See paragraph VI A 1 b in the basic DCP). NTS-2 will provide navigation signals which are compatible with the prototype satellites launched by the JPO and continue clock experiments to space qualify a cesium beam frequency standard. The three prototype satellites to be developed by the JPO (NDS 1-3) will be launched into subsynchronous orbits and will generate the navigation signals on board. These four satellites (NTS-2 and NDS 1-3) will be launched in FY 1976. They will be injected into orbital planes 120^{o} apart and appropriately phased in these orbits to provide up to 3-hour test periods per day with four satellites in view.

During Phase I, extensive use will be made of the ground-based simulation facility to support user equipment testing.

The ground station, to be used for tracking and control of satellites, will be developed and tested as a prototype of an operational ground station. The satellite configuration and ground station segment will provide a test environment, representative of the operational system, over selected test areas.

B. Phase II is primarily an initial operational test and evaluation (IOT&E) phase which culminates in a world-wide continuous, two-dimensional navigation and positioning capability for a selected group of users. Phase II includes (1) IOT&E and initial production of the low cost class of user equipment; (2) fabrication and completion of IOT&E for all other classes of equipment; and (3) development, fabrication and initial production of satellites to augment the NTS-1 and NDS 1-3 satellites launched in Phase I. An additional clock satellite (NTS-3) will be planned for and launched, if it is required. During the initial period of this phase, the satellites will be appropriately arrayed in orbit to provide up to eight hours of continuous four-in-view test time per day. After the IOT&E of user equipment is completed, the satellites will be uniformly distributed in their orbit planes to provide continuous, global, two-dimensional coverage for suitably equipped users. An initial production run of user equipment will be made for those users who elect to take advantage of the global two-dimensional coverage prior to the availability of the full DNSS capability in Phase III. The ground station will be placed in its operational configuration during this phase. Thus, by the end of Phase II, a global limited operational capability (LOC) will be available.

C. Phase III will implement the decision for the final operational configuration of the DNSS. Full production of all classes of user equipment will begin and, as sufficient satellites become available, the user community will be equipped with the requisite user equipment. OT&E of user equipment will be completed early in the phase. The exact number of satellites to be launched and maintained on orbit will be selected based on a number of factors such as support costs, coverage, and accuracy required.

D. An additional option (Alternative IVa) proposes a competitive procurement during Phase I for two additional generalized development models of user equipment. This option would provide increased competition for follow-on user equipment development contracts.

III. Comparison of Alternatives: Alternative IV differs in its development approach with the other alternatives. It is the first phase of an integrated, evolutionary development program leading to an operational system. This program is structured around progressive design-test-design cycles defined so as to produce extensive legacy of operational hardware from one phase to the next. Alternative IVa offers an optional competitive user equipment development effort during Phase I and reduces overall risk at a modest increase in development cost (see Table A2). The DT&E efforts of Phase I will be complete by CY 1977, IOT&E complete in CY 1980, and a limited operational capability will be available to users in CY 1981. This capability will be available world-wide and may be expanded incrementally to the full DNSS configuration.

The initial four-satellite test configuration of Phase I will support development testing of user equipment and satisfy the technical objectives in Section VA of the DCP. Unlike Alternatives I, II, and III, the final operational system will be functionally approximated during Phase I, providing extremely high legacy for the operational system. The specific orbital configuration will be defined at the completion of the initial tests (the baseline operational orbits are 12-hour circular with 60^{o} inclinations). Accurate clocks are required earlier in Alternative IV since the satellites are autonomous, processing satellites rather than the relay satellites of the first three alternatives.

Alternative IV provides program decision opportunities earlier than Alternatives I, II, and III, and provides a phased entry into an operational system.

IV. Impact on DNSDP Objectives: All technical objectives of the DNSDP can be satisfied by Alternative IV except item V.A. 2d concerning orbital altitude. This is not perceived as a critical item since desired system accuracy can be attained from the subsynchronous altitude program. Moreover, satellite weight, power, and cost considerations favor subsynchronous orbits. The system capability is essentially the same for all alternatives and will be fully demonstrated. A preferred DNSS design relating to user equipment, satellites and ground stations can be determined with the first phase results of Alternative IV. An extensive IOT&E program is accomplished in Phase II with results available in approximately the same time period as in Alternatives II and III. Sufficient IOT&E/OT&E capability is present in this development approach, time-phased in a sequence to support the recursive development of prototype and operational user equipment. The frequency and signal structure issues will be addressed early in the program. Evaluation of operational objectives requiring extended test periods for cost validation will be accomplished in the same manner as in Alternatives I-III. Sufficient numbers of user equipment will be produced to readily demonstrate achievement of reliability and maintainability goals (see Table A1). Reliable, low cost user equipment will be developed through three cycles of design-test-design to allow design optimization for low life cycle cost. The fabrication of production user equipment will occur sooner than with the development approach of the first three alternatives, allowing earlier operational evaluation (OT&E).

V. Impact on Test and Evaluation: Alternative IV provides a different test approach for the DNSS but uses the same sequential testing philosophy. The test schedule is phased with the development of both user equipment and the test environment. The number of subsynchronous satellites is expanded in a logical progression to allow all test objectives to be accomplished. The philosophy of providing the user with an environment identical to that of the full DNSS is not compromised. The constraints in available test time have been anticipated so that the concept of a sequential DT&E, IOT&E, and OT&E will not change. Testing will, in fact, be more realistic since prototype satellites and ground stations will be in use; thus, providing a complete demonstration of operational system capability.

VI. Risks: Overall program risks are reduced with this alternative, particularly engineering risks. The user equipment will develop through a series of trade-off studies and design-test-design iterations to insure optimization of performance, reliability, and cost as in Alternatives I-III. Alternative IVa further reduces risk through competitive development of user equipment. The satellite segment evolves directly from prototype to initial production to production with technological improvements derived in each successive phase, providing progressive updates and modifications. The ground segment will similarly evolve with no large changes in concept required. The satellite segment will have inherent redundancy during Phase II IOT&E because of the multiple satellites per orbital plane. A moderate increase in risk is associated with early selection of a specific DNSS navigation signal structure for the processing satellites. However, this risk is not appreciably greater than for the other alternatives since alternative signal structure designs are well-defined and the marginal advantage of further optimization is questionable. The processing satellites will also require accurate satellite clocks earlier in the program. NRL is concurrently advancing clock technology with a series of NTS satellites, leading ultimately to space qualification of a cesium beam frequency standard. The use of additional ground stations would have to be considered if clock accuracy is not fully achieved. This risk is present for all options.

VII. RECOMMENDATION: Alternative IVa is recommended. This alternative represents the most realistic approach for achieving the DNSDP objectives while proceeding in an evolutionary manner toward a full operational capability. The competitive user equipment development in Phase I provides increased competition for follow-on user equipment contracts.

TABLE A1

USER EQUIPMENT BY TYPE

	ALT I		ALT II		ALT III		ALT IV			ALT IVa		
	D	P	D	P	D	P	D	P	Pr	D	P	Pr
Army	15	15	15	15	24	24	6	22	22	8	22	22
Navy	4	-	8	-	8	6	2	12	14	2	12	14
Marine Corps	-	-	-	-	-	-	-	6	10	-	6	10
Air Force	10	8	10	8	16	8	6	14	16	6	14	16
DMA	-	-	-	-	-	-	-	4	-	-	4	-
Environmental Test	-	-	-	-	-	-	-	12	22	-	12	22
Spares	-	-	-	-	-	-	-	12	12	-	12	12
TOTAL	29	23	33	23	48	38	14	82	96	16	82	96

Notes:

1. Costs included in Table A2.

2. Table includes all units to be provided by Joint Program Office. (Does not include Service unique requirements.)

D - Development Models (ADU)
P - Prototype Models (EDU)
Pr - Production test articles (for OT&E)

TABLE A2

PROGRAM SCHEDULE AND COST ESTIMATES ('73 Constant $M)

CY: 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84

ALT	FY 74	75	76	77	78	79	80	81	82	83	84
I	DSARC I; NTS 1		DNSDP		NDS 1-4	DSARC II	FULL SCALE DEVELOPMENT		DSARC III	PRODUCTION	DNSS 1-24
	15.9	46.7	57.0	38.5	23.1	13.5					
II	DSARC I; NTS 1		DNSDP; NDS 5	NDS 6		NDS 1-4	DSARC II	FULL SCALE DEVELOPMENT			PROD. DSARC III
	14.9	39.1 (STP=4)*	88.1 (STP=3)*	57.2 (STP=2)*	18.8	19.8	8.7				
III	DSARC I; NTS 1		DNSDP; NDS 5	NDS 6		NDS 1-4	DSARC II	FULL SCALE DEVELOPMENT			PROD. DSARC III
	15.6	43.6 (STP=4)*	93.8 (STP=3)*	60.7 (STP=2)*	18.8	19.8	8.7				
IV**	DSARC; NTS 1	PHASE I	NTS 2	NDS 1-3	◇	NTS 3; PHASE II	NDS 4-9	3 NDS SPARES; LOC	◇	PHASE III	DNSS 1-18
	9.2	25.2	52.7 (STP=11)*	24.4 (STP=7)*	6.9						
** IVa***	9.2	27.2	54.7	25.4	6.9						

*Space Test Program booster and launch costs included in program cost estimates.
**See TABLE A3 for Cost Breakdown.
***Competitive User Equipment.

TABLE A3

PROGRAM COST BREAKDOWN ('73 Constant $M)

ALTERNATIVE		FY 74	75	76	77	78	79	80	DNSDP TOTAL	Estimate to Completion (DNSS)
I	Army	1.9	3.7	4.5	4.5	5.1	6.5		26.2	
	Navy	3.0	3.0	2.5	2.0	2.0	2.0		14.5	
	Air Force	11.0	40.0	50.0	32.0	16.0	5.0		154.0	
	TOTAL	15.9	46.7	57.0	38.5	23.1	13.5		194.7	280
II	Army	1.9	3.7	4.6	4.6	5.1	6.5	3.7	30.1	
	Navy	3.0	6.0	7.0	3.6	3.3	3.3		26.2	
	Air Force	10.0	29.4	76.5	49.0	10.4	10.0	5.0	190.3	
	TOTAL	14.9	39.1	88.1	57.2	18.8	19.8	8.7	246.6	281
III	Army	1.9	4.2	5.8	5.6	5.1	6.5	3.7	32.8	
	Navy	3.0	6.0	8.5	4.1	3.3	3.3		28.2	
	Air Force	10.7	33.4	79.5	51.0	10.4	10.0	5.0	200.0	
	TOTAL	15.6	43.6	93.8	60.7	18.8	19.8	8.7	261.0	281
IV	Army	.5	.6	3.0	3.6	1.2			8.9	
	Navy	.6	2.7	4.7	3.3	1.7			13.0	
	Air Force	8.1	21.9	45.0	17.5	4.0			96.5	
	TOTAL	9.2	25.2	52.7	24.4	6.9			118.4	357
IVA	Army	.5	.6	3.0	3.6	1.2			8.9	
	Navy	.6	2.7	4.7	3.3	1.7			13.0	
	Air Force	8.1	23.9	47.0	18.5	4.0			101.5	
	TOTAL	9.2	27.2	54.3	25.4	6.9			123.4	357

The above costs do not in all cases correspond to the earlier Service Base POM submissions and the FYDP and are identified for planning purposes.

Notes:
(1) NTS-1 Development costs not included but does include costs of JPO testing of NTS-1 necessary to support DNSS development.
(2) Includes space test program booster and launch costs, except for NTS-1.
(3) Service unique testing not included