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MODIFIED AUTOMATIC DEPENDENT SURVEILLANCE SYSTEM (M-ADS) FOR THE NORTH SEA HELICOPTERS

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Abstract

The helicopter traffic over the North Sea is performed in uncontrolled airspace over international waters. The lack of radar coverage makes the establishment of controlled airspace difficult. The development of Automatic Dependent Surveillance (ADS) and use of satellite technology for Navigation, Communication and Surveillance (NCS) have made it possible to evaluate Modified Automatic Dependent Surveillance (M-ADS) as a basis for establishing controlled airspace over remote areas without radar coverage.

1. Introduction

North Sea Air Traffic

The Air Traffic Control (ATC) services for Norwegian offshore helicopter traffic has been below acceptable standard for many years. Norwegian Civil Aviation Athorities (NCAA) have previously taken the position that the offshore traffic is private charter traffic operating in international, uncontrolled airspace and hence outside Norwegian control. With a fleet of nearly 40 offshore helicopters, flying around 40.000 hrs a year, transporting about 900.000 passengers annually, this situation is not acceptable. This situation led to the International Federation of Air Line Pilots Association (IFALPA) in 1991 defining the North Sea area as Black Star Airspace. This means that the standard of Air Traffic Control (ATC) is below International Civil Aviation Organisation (ICAO) accepted standard.

SINTEF Report

In 1990, the Norwegian research organisation SINTEF (The Foundation for Scientific and Industrial Technology Research), conducted a safety research project on behalf of Norske Shell and Statoil, with active participation by Helikopter Service (HS). In the report which came out in 1990, significant risk factors associated with helicopter transportation over the North Sea were defined and described. It was concluded that ATC, navigation aids and services made up the second highest risk factor after technical reliability of helicopters.

Helikopter Service' safety program.

These findings were no surprise to Helikopter Service, which at the time, was evaluating both HUMS systems, to reduce the risk from low technical reliability, and new navigation systems to reduce the risk from navigational errors. Helikopter Service looked at these evaluations as elements of an active safety programme, working on improvements to helicopter safety. The SINTEF report was a welcomed tool for continued progress in this field.
The work so far has resulted in a company official commitment of being a leading company regarding helicopter operations in general, and flight safety in particular. These are the background and the reasons for Helikopter Service to take an active part in the North Sea ADS trial.

Statoil/Kongsberg Navigation - Traffic surveillance project.

The M-ADS project started as a Statoil funded research project performed by Kongsberg Navigation Norway. The project "Helicopter Traffic Surveillance" was initiated by Statoil to investigate the possibilities of tracking offshore helicopters by use of existing and future means. KN concluded in their report that tracking by use of High Frequence (HF) radio was the overall best solution, since satellite communication would be too expensive.
This solution was discussed with Statoil, NCAA and helicopter operators in June 1991. Both Statoil and the operators disagreed with KN regarding use of HF, and strongly adviced KN to look more closely at Satellite Communication (SATCOM). This view was also favoured by NCAA which now had taken a strong interest in the concept. This caused KN to go back to the drawing board and in late 1991 they issued a new proposal, based on SATCOM. By now NCAA had taken over the project and invited Statoil, Shell and Norsk Hydro to participate as sponsors for the project. Since HS had taken an active part in the project definition phase together with KN, HS was invited by NCAA to participate actively in the project, since HS was the best qualified operator with expertise within avionic engineering and operational involvement in GPS evaluation.

2. Global Positioning system (GPS)

HS has continuously monitored the development of navigation systems and was during the 1980-ies a strong supporter of a Norwegian Loran-C chain. However, due to political reasons this chain was never decided upon in the 1980-ies (decided on in 1992, 5 years too late), and HS initiated an evaluation program evaluating various types of navigation systems/sensors, which in 1990 also included GPS. In 1990 HS installed Global Wulfsberg GNS 500A-5 with GPS in the S-61N fleet, and in 1991 we installed GPS sensors in AS 332L equipped with Racal RNAV 2 navigation systems. Already in mid 1991, with only 16 satellites operational, we had 24 hrs with 2-dimensional navigation coverage (with altimeter aiding), and our GPS evaluation results showed that the GPS navigation system already was far superior to the other navigation systems, including Omega/VLF, Loran-C, Doppler and Decca, regarding navigation accuracy and reliability. Since October 1992, with 19 satellites operational at that time, we have had 24 hrs, 3-dimensional GPS navigation coverage. HS policy is to install GPS navigation system in all new aircraft and is continuously evaluating the option of installing GPS in older helicopters. By mid 1993, 90% of the fleet was equipped with GPS and HS is now the most experienced GPS user operating over the North Sea. The full 24 satellite GPS system was declared Initial Operational Capable (IOC) by US Department of Defence (USDOD) in late 1993, and was declared Full Operational Capable by USDOD in 1994. US Federal Aviation Administration (FAA) approved the system as a supplemental navigation system in US airspace in early 1994. US DOD and FAA are committed to support civil use of the GPS system, and its applications including DGPS, is accelerating at a fast pace world wide.

3. Automatic Dependent Surveillance (ADS).

The new ICAO Future Air Navigation System (FANS) concept is including use of satellite technology for navigation and communication. Up to now transoceanic flights have relied on HF radio for communication. This has resulted in different kinds of communication problems, since HF is susceptable to atmospheric disturbances. The FANS concept includes Automatic Dependent Surveillance (ADS) which is a system that automatically transmit position reports and other messages (like Health and Usage Monitoring System, HUMS data), information about passengers/cargo and traffic information/clearances from the aircraft to ATC and vice verse, via International Maritime Satellite (INMARSAT). By use of ADS the short comings of VHF and HF radio communications are overcome. This system has been under evaluation for some time. Likewise, satellite relay of telephone messages to/from aircraft are being implemented. The ICAO decision on FANS/ADS combined with the Statoil/Kongsberg Navigation study of Helicopter Traffic Surveillance, triggered NCAA's interest in developing a North Sea ADS trial. Hence we got the Modified ADS (M-ADS) system. NCAA see the M-ADS concept having the potential of becoming a substitute of radar surveillance in the North Sea, and hence to upgrade parts of the airspace from uncontrolled to controlled.

4. Modified Automatic Dependent Surveillance (M-ADS).

Operational Goals

The purpose of the M-ADS is to provide helicopter surveillance data for maintaining safe separation of helicopters and to allow improved airspace capacity and more efficient operations over the North Sea. This will be accomplished by providing information to the ground-based peer of the M-ADS, the M-ADS processor (M-ADSP), which will enable it to estimate helicopter position, and to make short term and long term predictions of where the helicopter will be at a specific future time. The helicopter avionics will provide information on its present position, short term and long term intent, local meteorological data, and occurrence of certain events.

Operational Applications.

M-ADS is intended to provide automatic periodic position and event-driven reports to the M-ADSP at ground-specified intervals. Helicopter avionics will be installed and/or modified to generate these M-ADS reports. The M-ADSP will subsequently process the information to validate and correlate the M-ADS position reports with the flight plan.

M-ADS System Overview.

M-ADS is a service for use by air traffic services (ATS) in which helicopter automatically transmit, via a data link, data derived from on-board navigation systems. As a minimum, the data include three-dimensional position, the corresponding time of the position data, and a Figure of Merit (FOM) that characterises the accuracy of the position data. Additional data may be provided as appropriate. (Adapted from the Future Air Navigation Systems (FANS)/4 Report, Dcoument 9524).

Airborne components of the M-ADS System.

The airborne components of the M-ADS system are as follows:

* Pilot interface;

* Avionics encompassing the M-ADS function; and

* Air Traffic Network (ATN) Interface.

The M-ADS reports are transmitted automatically without pilot action. The frequency of reporting is determined by the ground-based M-ADS prosessor system; however, a capability shall be provided to permit emergency mode reports to be initiated/terminated by the pilot.

The M-ADS capability is supported by avionics equipment that is able to gather helicopter data from on-board systems, format them and pass the messages to the helicopter ATN router for transmission to the relevant air-ground link.

On-board equipment should also be capable of receiving messages originated by the M-ADSP that will define reporting paramters, including report update rate, events and the data fields to be included in the report.

Ground-Based Components of the M-ADS System.

The ground-based components of the M-ADS system include:

* ATN Interface;

* ATS ground-based peer of the airborne M-ADSP;

* ATS (controller).

5. M-ADS - Phase I

M-ADS project.

NCAA invited STATOIL, SHELL, NORSK HYDRO, INMARSAT, NORWEGIAN TELECOM and HELIKOPTER SERVICE to participate in a North Sea ADS trial project. Since this was the first known installation of SATCOM equipment in helicopters, certain modifications were necessary. Hence the ADS system was renamed Modified Automatic

Dependent System (M-MADS). A complete ADS trial system, including the airborne package for installation in the Sikorsky S-61N helicopter, and a ground station for installation at Eik Ground Earth Station (GES) was supplied by INMARSAT. NORWEGIAN TELECOM was responsible for the data transmission from Eik GES to Stavanger ATC. HELIKOPTER SERVICE was responsible for the installation, flight testing and operation of the installed ADS trial system. Statoil, Shell and Norsk Hydro made funds available for the M-ADS trial.

The M-ADS Trial Project Organisation included:

- STEERING COMMITTEE
  - NCAA
  - STATOIL
  - NORWAY TELECOM
  - NORWAY TECHNICAL UNIVERSITY

- PROJECT GROUP
  - NCAA
  - NORWAY TELECOM
  - HS

- REFERENCE GROUP
  - Braathens Helicopter
  - Helikopter Service
  - Mørefly
  - Widerøe
  - RNoAF
  - Statoil
  - Shell
  - Hydro

M-ADS installation.

The M-ADS package was installed in the S-61N cabin in lieu of two passenger seats. The equipment weighed 80 kg and occasionally one operator was included on the flights. Hence, Statoil lost one to two passengers on the evaluation flights. The system used navigation data from the S-61N GPS system, and a SATCOM antenna was mounted on the aft, top fuselage. The system was fully automatic and needed no interaction by the crew.

M-ADS trial.

The test plan called for installation of one M-ADS system in a HS S-61N helicopter, flying out of Bergen on the Statfjord track. The test Phase I was planned to commence in April -92 and last three months. Due to some technical problems with the equipment, the installation was delayed and the ADS package was test flown in beginning of June -92. The Phase I testing was now underway and was planned to be completed in September -92, however, several equipment malfunctions caused several delays in the program. In order to get enough data, the program had to be stretched to the end of January -93. During the trial period, approximately 300 operating hours were accumulated and approximately 3.000 Automatic Position Reports were sent, of which 2.313 were received in Stavanger and London.

M-ADS test results.

The data transmissions to Stavanger ATC soon showed that there were occasionally missing reports, which were transmitted every 5 minutes from the helicopter. After measuring the antenna reception characteristics, the antenna diagram showed marked notches caused by masking and reflections of signals. The results clearly indicated that on certain headings the relative position of the satellite coincided with one characteristic notch in the antenna diagram. This resulted in lost data transmissions on the return leg on the Statfjord track. This prompted the project group to decide on evaluating the use of two satellites, including the Atlantic West satellite over South America, in addition to Atlantic East over West Africa. This did not cure the problem, however, due to a coincidence of very strong wind from west during the test period, which resulted in more helicopter drift and hence causing the antenna diagram notches to again coincide with the satellite relative direction. However, the concept was proven and the test results indicated that there were no major obstacles to prevent a M-ADS concept to be implemented. The major significance of the test results were that the data signals were unaffected by rotor modulation, and with a suitable antenna position the data stream should pass unrestricted.

Conclusion - Phase I.

It was concluded that Automatic Dependent Surveillance of North Sea offshore helicopters was feasable and that the M-ADS Phase II should continue.

6. M-ADS - Phase II

Project progress.

Norsk Forsvarsteknologi (NFT, Norweigan Defence Technology) was initially given a project definition contract, including the task of preparing a M-ADS system specification. This was completed in 1993. In early 1994 NCAA issued a contract to NFT to develop, test and qualify a M-ADS unit for helicopters. NFT has issued a sub contract to Racal Avionics, UK to produce the SATCOM equipment for NFT, which will be responsible for system integration, testing and qualification. Helikopter Service has now joined the group of sponsors and will act as a subcontractor to NFT, being responsible for the engineering and installation, and together with NFT testfly the systems. NCAA will be responsible for the system infrastructure and certification.

Administration.

NCAA, together with NFT and the sponsors (Statoil, Shell, Hydro, other Norwegian oil companies and Helikopter Service), has formed a Steering Committee which will control the development work in Phase II.

NCAA responsibilities - Phase II.

NCAA is responsible for:

- Project management.
- Quality control.
- Certification of M-ADS.

NFT responsibilities.

NFT is responsible for:

- Total system integration, testing and qualification.
- Development of the M-ADS unit according to the approved specification.
- Perform testing of the M-ADS equipment in cooperation with NCAA and HS.
- The responsibility for the technical and commercial aspects of the subcontracted SATCOM part of the M-ADS project.

Sponsor responsibilities.

The sponsors are responsible for:

- Statoil, Shell, Norsk Hydro and Helikopter Service (of which Statoil has the Chair of the Steering Committee) were the launch sponsors for the M-ADS project.
- Additional Norwegian oil companies have joining the sponsor group, and will pay a pro rata share of the development costs.

HS responsibilities.

HS responsibilities :

- Engineering, installation and testing of the of the M-ADS equipment in Norwegian offshore helicopters.
- Perform operational evaluation/testing of the M-ADS equipment in cooperation with NCAA and NFT.

Guaranties.

- NFT will guarantee the completion of the project.
- NCAA will guarantee certification of the M-ADS equipment.
- NCAA will contribute to the international certification of the equipment.

Project status.

- The Phase II activities are in progress.
- The M-ADS unit is in development
- The SATCOM units are in development

7. Weight/Volume

Box	Volume	Weight
SDU/RFU	2 MCU (= 1/4 ATR box)	4,5 kg
HPA	2 MCU	4,5 kg
LNA/DIP	280 x 197 x 50 mm	2,0 kg
LGA	275 x 120 x 100 mm	1,0 kg
SATCOM	4 MCU	12,0 kg
NFT M-ADS UNIT	2 MCU	4,0 kg
TOTAL M-ADS	6 MCU	16,0 kg

8. Timeframe

Phase II development - 2 years	1994 - 96
M-ADS unit production model	1995
INMARSAT Phase II test	1996
M-ADS certification	1996
Installation in 2 A/C	1996
Series production (2-3 M-ADS units pr. month)	1997 - 98
Installation in offshore A/C	1997 - 98

9. Preliminary Phase II cost figures

- M-ADS unit, development/testing/certification of 2 units:	4,0mill. USD
- M-ADS production unit cost:	20.000 USD
- SATCOM units, development of a helicopter type:	1,0 mill. USD
- SATCOM production unit cost:	0,18 mill. USD

Preliminary, total Phase II development cost, mill. USD

	1994	1995	1996	SUM
M-ADS unit	2	1,5	0,5	4
SATCOM	0,6	0,4	-	1
TOTAL	2,6	1,9	0,5	5

Preliminary operating cost.

- Approx. 25 USD pr. hr.

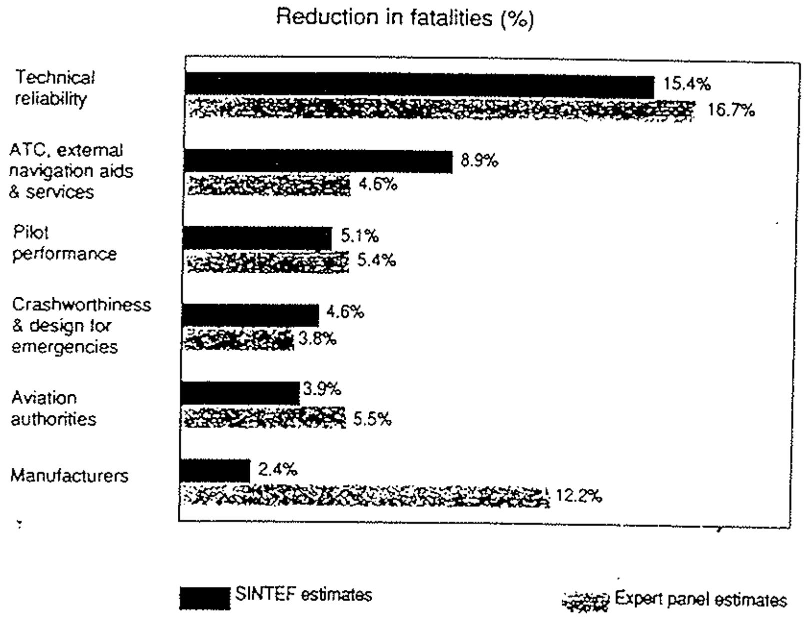
10. Conclusions

- The M-ADS project Phase I was successfully completed.
- The North Sea M-ADS concept has been proved to work.
- The Phase I report was issued in April 1993.
- The Phase II is in progress and is planned completed in 1996.
- The M-ADS system is planned operational in 1997/99.
- The M-ADS system will significantly increase the level of safety by reducing the risk of mid air collisions over the North Sea, and allow continuous surveillance of the North Sea air traffic.
- The introduction of M-ADS in the North Sea may result in upgrading parts of the airspace from Class G (uncontrolled) to Class E (controlled).

References

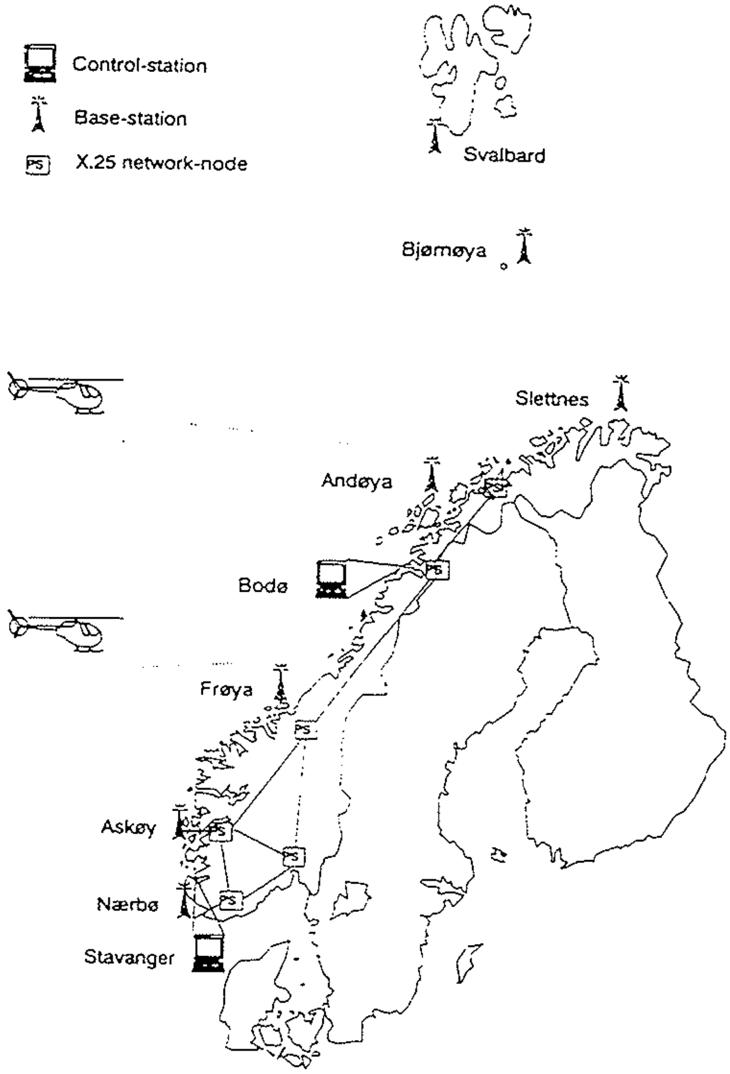
1. ICAO Document 9524; Future Air Navigation System (FANS) 14 Report.

2. NCAA report; Modified Automatic Dependent Surveillance Trial, 1993.



Reduction in fatalities, following realistic improvement of risk factors (according to SINTEF and a group of helicopter experts)

FIGURE 1. POTENTIAL RISK REDUCTION.



Schematic network architecture based on
use of HF-radio

FIGURE 2. HF-RADIO NETWORK.

ATS Applications:
Automatic Dependent Surveillance

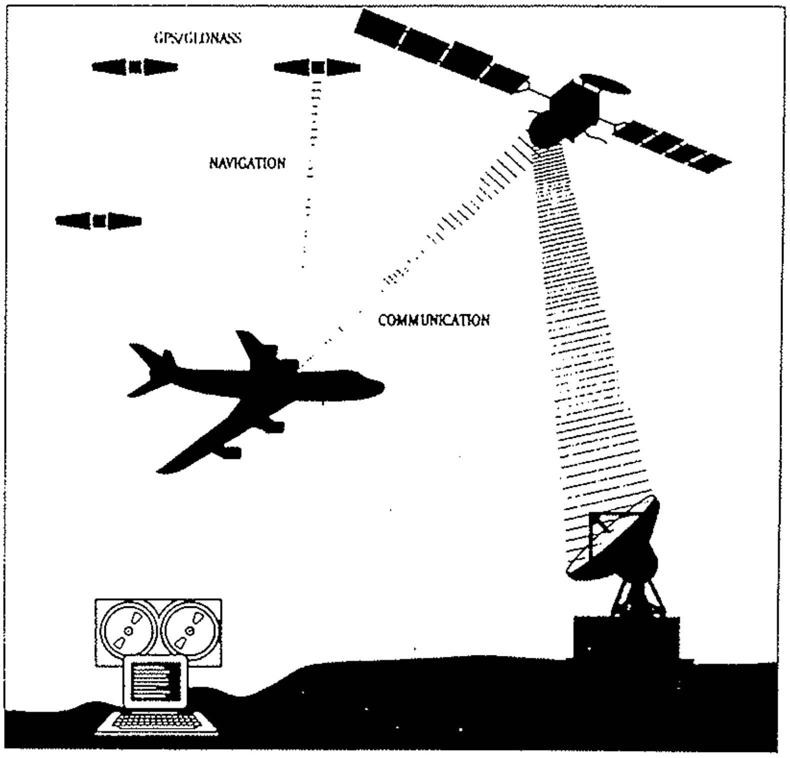


FIGURE 3. AUTOMATIC DEPENDENT SURVEILLANCE.

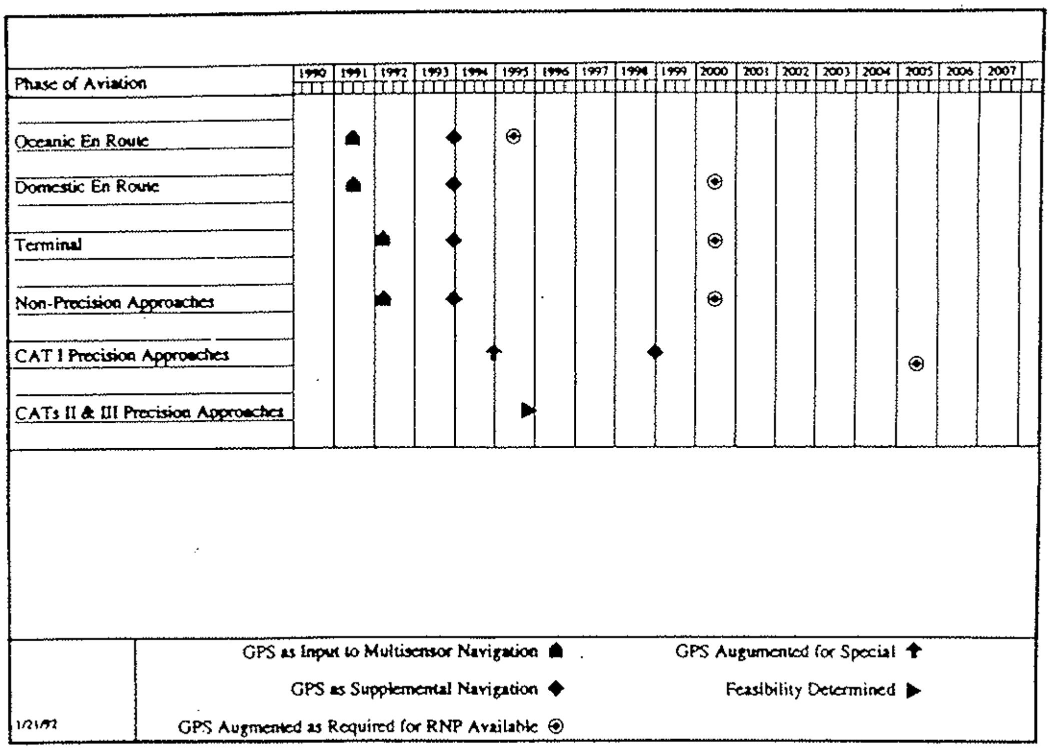


FIGURE 4. FAA GPS PLAN.

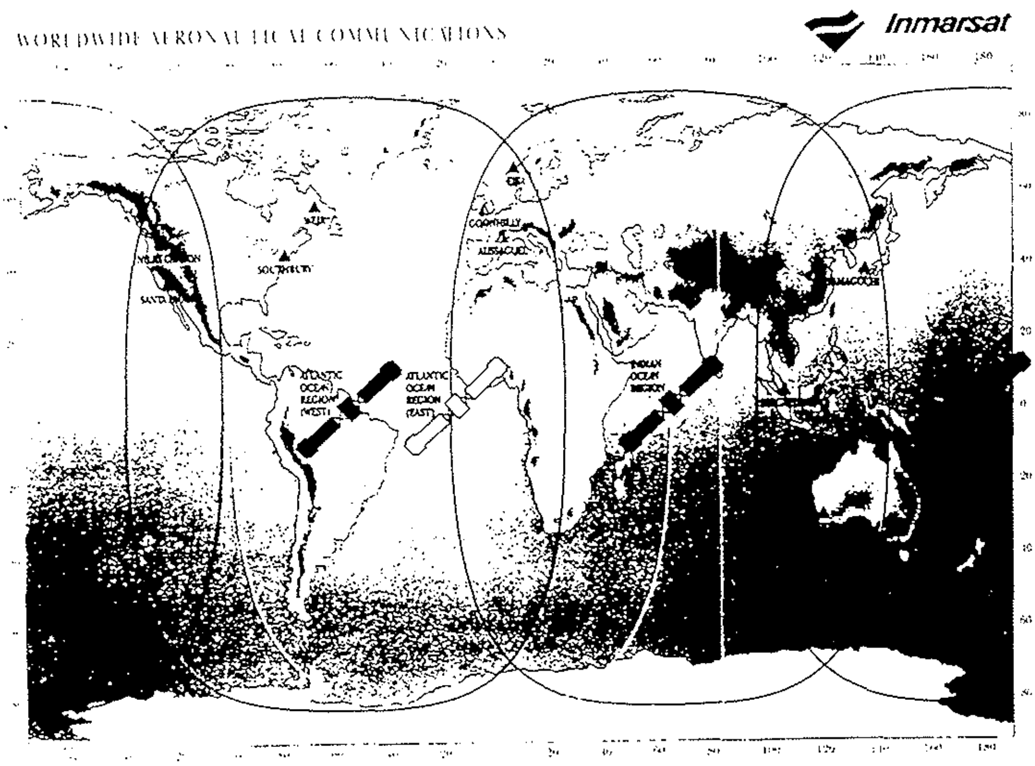


FIGURE 5. INMARSAT COVERAGE.

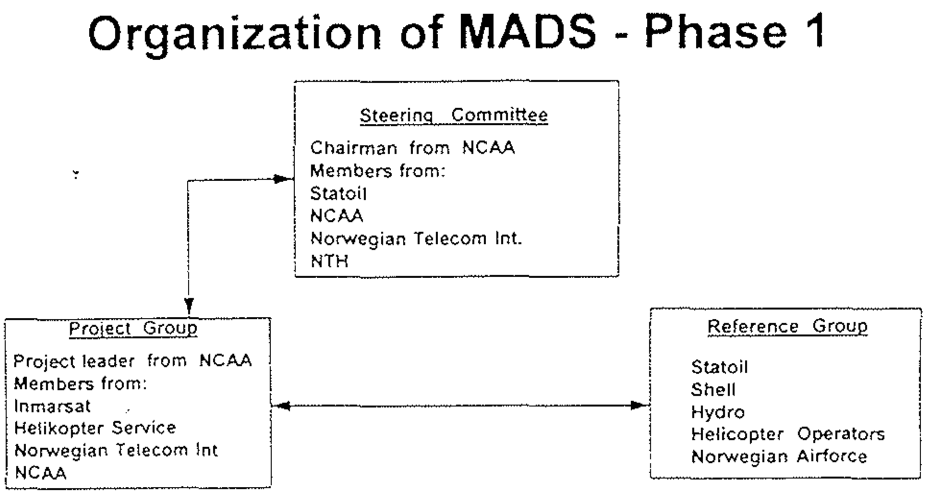


FIGURE 6. M-ADS PHASE 1.

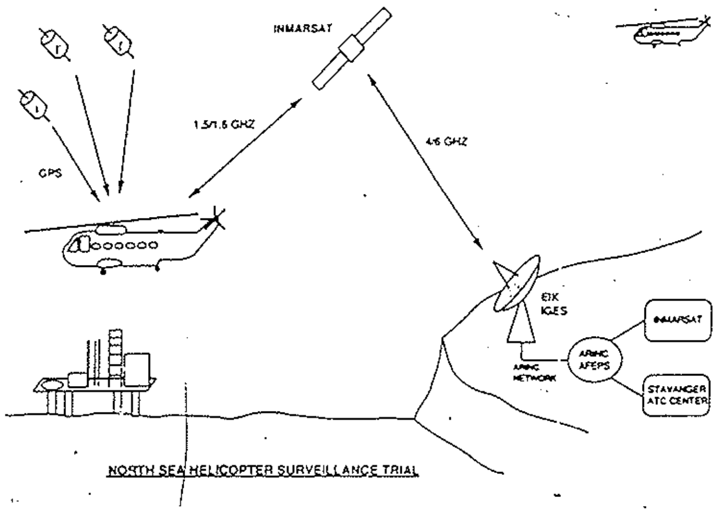


FIGURE 7. NORTH SEA M-ADS TRIAL.

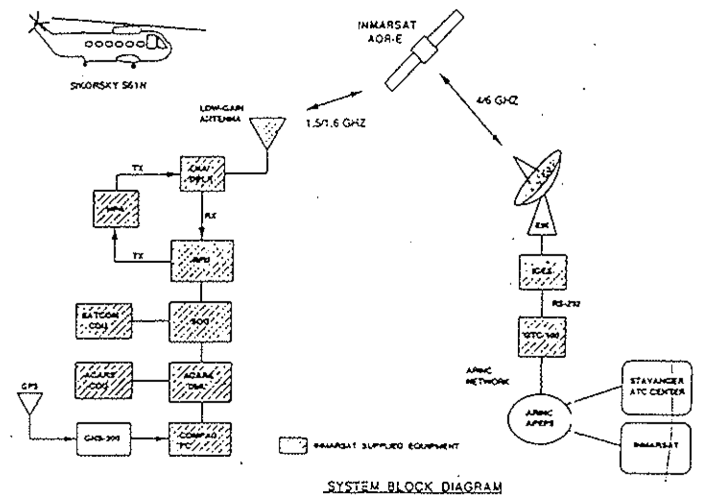


FIGURE 8. M-ADS SYSTEM TRIAL.

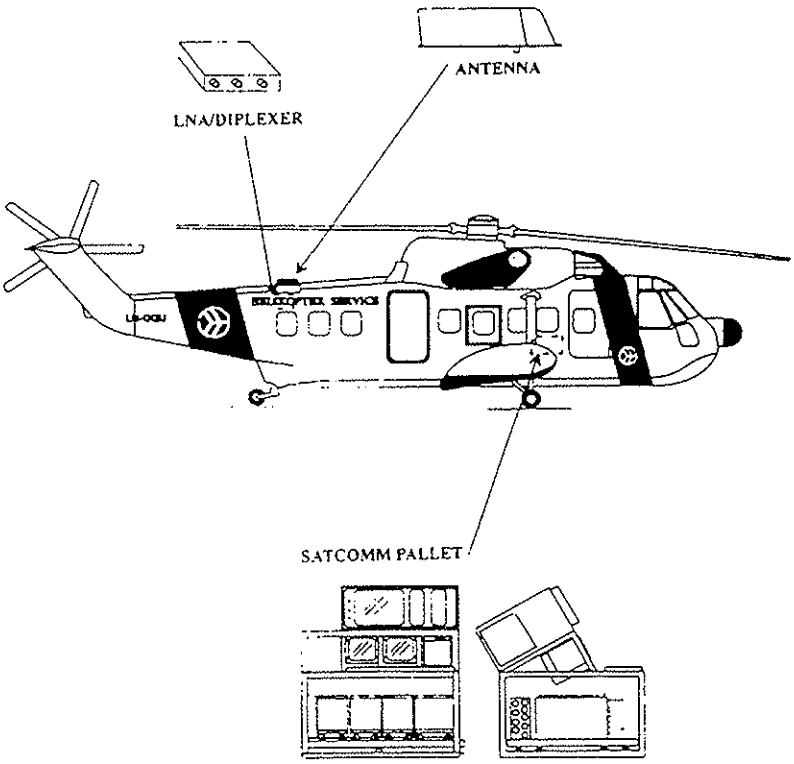


FIGURE 9. S-61N SATCOM.

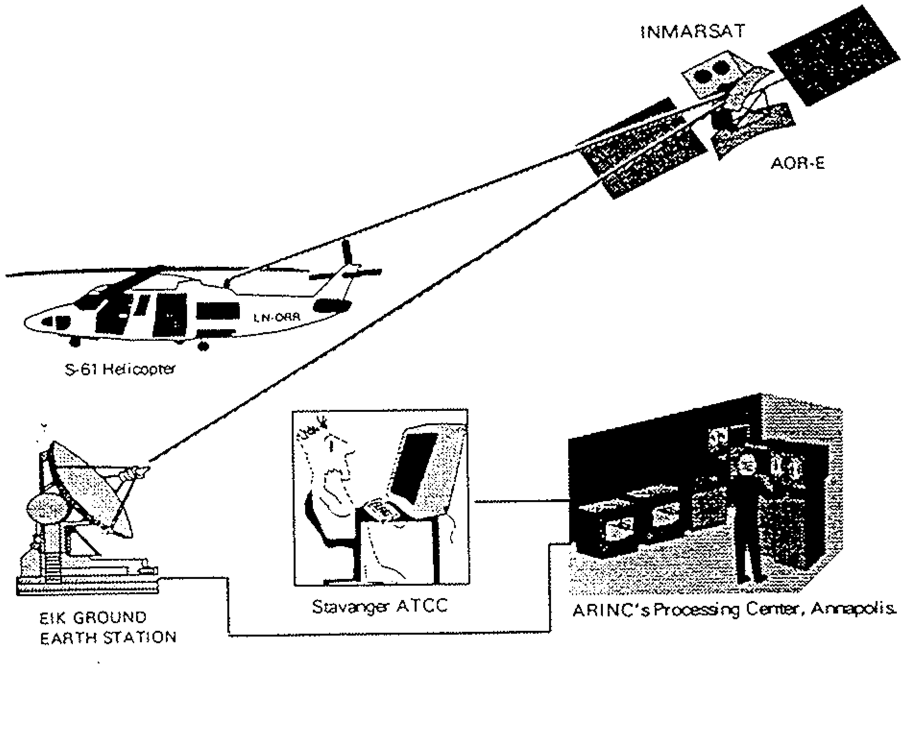


FIGURE 10. SATCOM LINK.

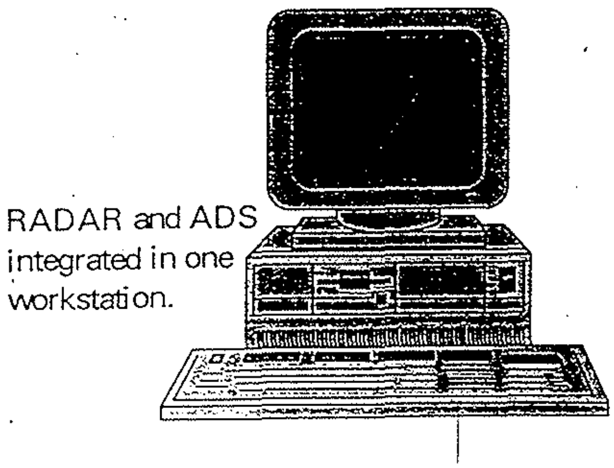


FIGURE 11. RADAR/M-ADS WORK STATION.

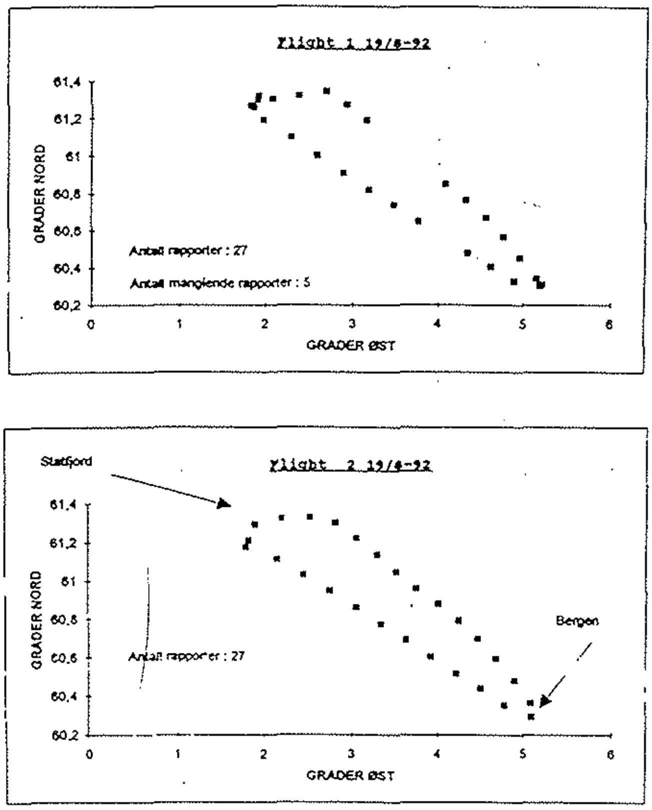


FIGURE 12. POSITION PLOTS.

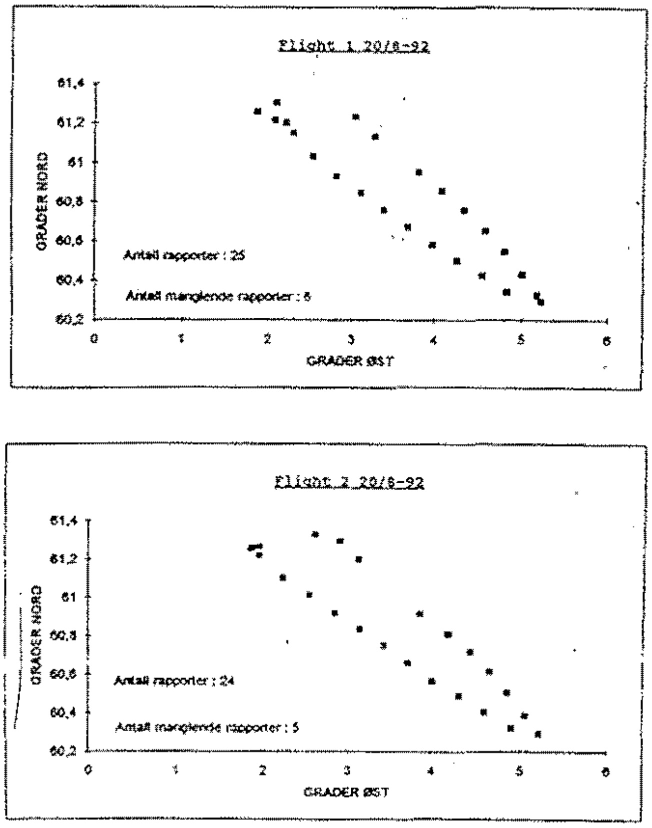


FIGURE 13. POSITION PLOTS.

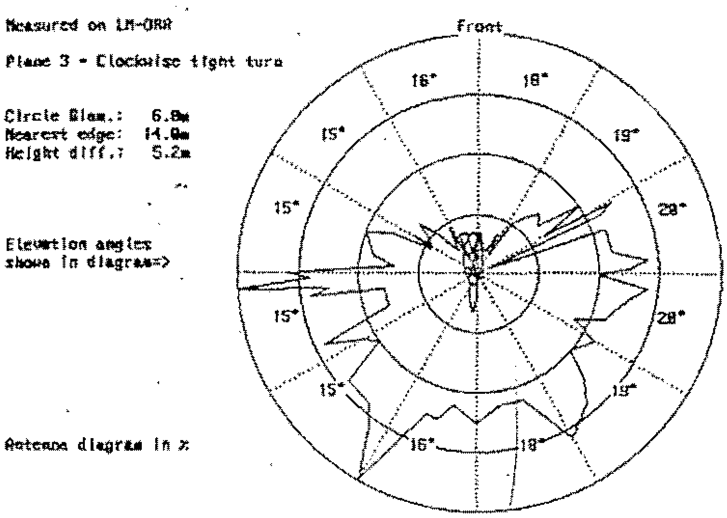


FIGURE 14. ANTENNA DIAGRAM.

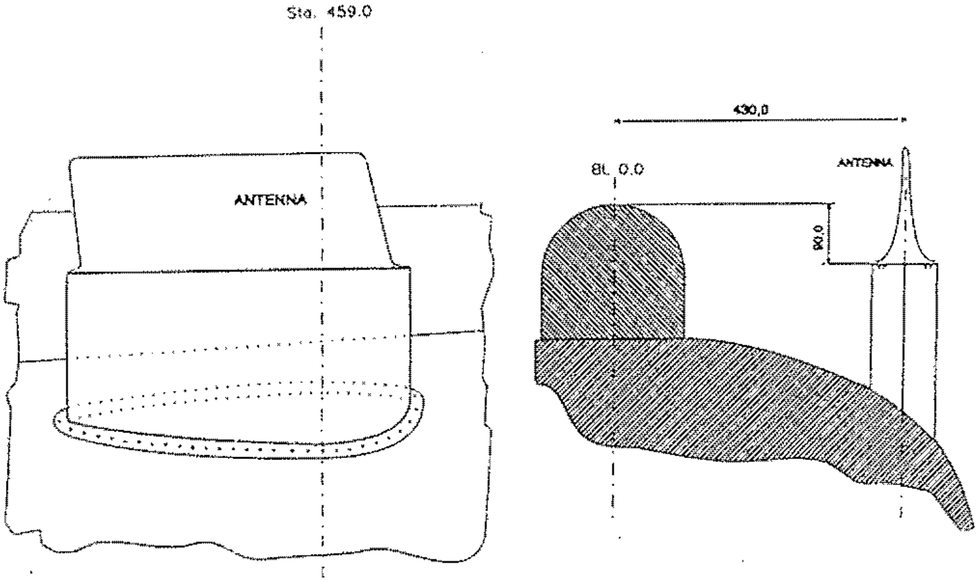


FIGURE 15. ANTENNA MOUNTING.

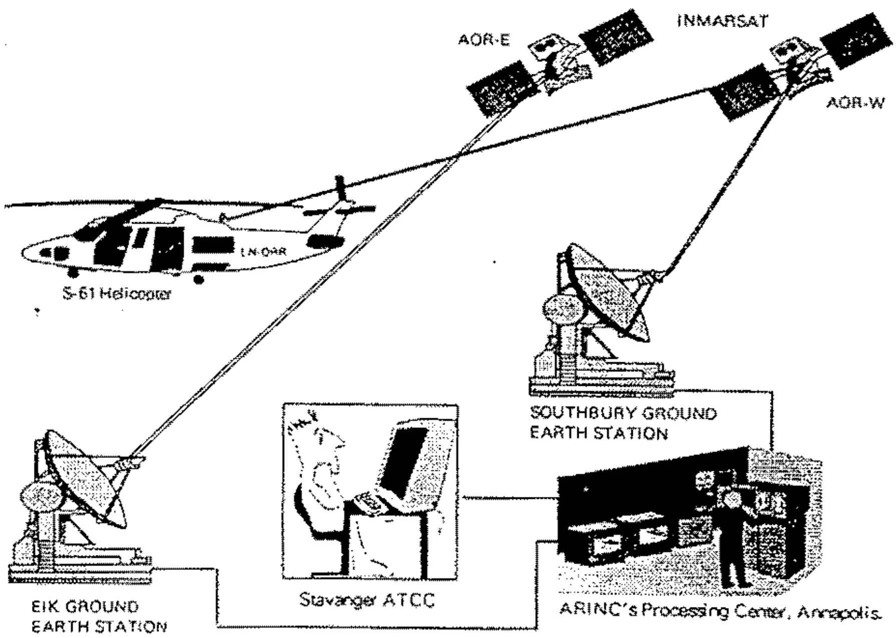


FIGURE 16. SATCOM MULTI LINKS