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TETHERED ROTORPLATFORMS AND THEIR MISSION POTENTIAL

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1. ABSTRACT

After a definition of tethered rotorplatforms and the main objectives that are pursued with these vehicles a short retrospect on rotorplatform history is given.

Then the Dornier "Kiebitz" will be desribed. It is designed to lift payloads for battlefield surveillance, air defence, EW or communication to some hundred meters above ground for long mission times.

In the second part of the paper a very small tethered rotorplatform for elevating electro optical sensors of 5 to 10 kg will be presented. The energy for its flight time of about 70 seconds is stored in a massive momentum ring surrounding its rotor.

Finally a rotorplatform with an electric drive system for payloads of about 30 kg will be proposed, mainly for target acquisition and target designation.

2. DEFINITION

Tethered rotorplatforms are unmanned helicopters connected to a ground station by means of a tethering cable. Besides fixing of the rotorplatform position the tethering cable can provide ECM-proof data transmission and supply the rotorplatform engine with fuel or, if it is driven by an electric motor, with electric power. The continuous supply of the platform engine leads to a mission endurance not obtainable by other flight vehicles.

The main objective of tethered rotorplatforms is to elevate sensors or transmitters to an operating height at which the maximum range of these systems can be utilized without considerable restriction by terrain roughness and vegetation. The operating height is limited to some hundred meters by the tethering cable, but if favourable topographical positions are chosen, intervisibility in distant areas of interest is possible.

3. ROTORPLATFORM HISTORY

The first tethered rotorplatform, that was successfully flight tested up to a height of 45 m above ground was constructed during world war I by Stefan Petróczy and Theodore von Kármán. *(Fig. 1)*.

It was tethered by three cables fixed at the end of three cantilevers of the fuselage and driven by three aeroplane motors of 120 HP each. The maximum flight time has been one hour. Lacking the achievements of modern electronics it was necessary to use a pilot instead of an automatic control and an observer instead of reconnaissance sensors.

Similar in respect to tethering and stabilization by three cables was the rotorplatform of the german company AEG built and tested up to a height of 750 m above ground during world war II *(Fig. 2)*. The electric power for the 200 kW electric motor was transmitted through the tethering cables. The platform was designed to carry an observer or alternatively to lift long wave radio antennas. Development was stopped before the system became operational.

During the Sixtieth Westinghouse in Canada, Nordaviation in France and different companies in USA tested various kinds of tethered rotorplatforms.

In FRG Dornier started the development of tethered rotorplatforms in 1965 with a small experimental predecessor of the Dornier "Kiebitz" *(Fig. 3)*. At more than 100 flight hours it demonstrated the practicability of the chosen tethering and stabilization concept.

4. TETHERED ROTORPLATFORM "KIEBITZ"

The encouraging results of the Kiebitz predecessor flight evaluation lead in 1972 to a German Army requirement for a tethered rotorplatform for different military missions. Dornier was awarded a contract by the German MoD to develop the rotorplatform system, that we named "Kiebitz". It consists of a stabilized flight vehicle, a tethering cable and a ground station on a cross country vehicle *(Fig. 4)*.

Dynamic System (Fig. 5)

Rotor drive is by ejection of compressed air at the blade tips. The compressed air is produced by a radial compressor powered by an Allison 250-C 20 B gas turbine. It is ducted through rotor head and rotor blades to the tip nozzles, preventing rotor icing under all conditions because its temperature is increased by compression. The turbine exhaust gas is conducted to two yaw control nozzles.

This reaction propulsion system eliminates the need for a tail rotor thus allowing a small symmetrical air frame with the advantage of reduced detectability and eased ground transport.

Stabilization System

The basic control system consists of:

- attitude stabilization in pitch and roll, combined with translation damping
- angular velocity control in yaw,
- cable tension and rotor rpm control.

The system operates with the exclusive aid of airborne components consisting of an autopilot electronic unit and measuring sensors. The only tasks of the operator in the ground station are to control the cable winch, to preset values for Kiebitz heading and lateral offset and to monitor instruments. Pilot qualification is not necessary.

The operator can choose between three types of control *(Fig. 6)*. In the "attitude control" mode, the vertical attitude of the air vehicle is stabilized and the position over the ground is allowed to vary, depending on wind. In the "position control" mode, the position of the air vehicle relative to the ground station is maintained, and the air vehicle must be tilted to compensate for wind forces. In the "drift control" mode, the lateral offset relative to the ground station is determined by the operator to an amount of maximum 100 m.

The lateral offset reduces the vulnerability of the ground station by artillery.

Tethering Cable (Fig. 7)

The tethering cable between ground station and flight vehicle has four functions:

- Tethering of flight vehicle
- Continuous fuel supply
- Transmission of control and monitoring signals
- Transmission of sensor signals

The coaxial cable and the shielded dual line transmit sensor signals from the flight vehicle to the ground station, while 72 insulated wires relay control and monitoring signals and take up the tension forces of the tethering cable.

Ground Station

The ground station is designed for autonomous operation and transportation of Kiebitz. It is accomodated in a container that can be transported by truck, by train or by airplane. Its main components are

- Take-off and landing pad
- Cable winch system
- Fuel supply system for the rotorplatform
- Operators compartment

For operation of the sensor payload and sensor data processing another vehicle is provided. Data transmission between the two ground stations is by wire connection.

Flight performance (Fig. 8)

The flight envelope of Kiebitz is determined by the available rotor thrust, the available length of the tethering cable and the load capacity of the airframe structure with respect to maximum payload.

The tether altitude of 300 m is a military requirement for a battlefield surveillance system. It was selected after studies and tests indicated that this altitude provided a significant improvement for intervisibility in the type of terrain found in Central Europe, while still remaining low enough to minimize own detectability and vulnerability.

By modifications of the winch system the tether altitude could be increased considerably.

5. MISSION POTENTIAL OF KIEBITZ

KIEBITZ has been designed as a multi-purpose carrier system for different sensors and transmitters. Selection of missions for KIEBITZ generally will be based upon the utility of its characteristic features:

- mobile
  by operation from a cross-country vehicle
- permanently operational
  by energy supply from ground station
- autostable
  by automatic stabilization system
- all-weather operational
  by position keeping with tethering cable and icing-proof rotor system
- ECM-proof data transmission
  via tethering cable
- low detectability
  because of small dimensions

Battlefield surveillance

The first application of KIEBITZ will be for battlefield surveillance and target acquisition for areal weapons. In German-French cooperation the ARGUS-system is being developed combining the carrier system KIEBITZ of Dornier with the MTI-radar system ORPHEE of the French company LCT. The German and the French Armies intend to introduce the ARGUS system in 1986.

At Dornier two prototypes of ARGUS are being tested in flight. With ARGUS it will be possible to detect moving targets in a distance of more than 50 km. Due to the wide range of its radar ARGUS can be located in adequate distance from the FEBA in order to reduce vulnerability.

Interesting parts of the battlefield can be surveilled continuously for 24 hours if required. Alternatively KIEBITZ could be equipped with an IR flash detector to triangulate on artillery or missile launch sites with sufficient accuracy for direct counter-battery fire.

Electronic warfare

Different Armies are considering the use of elevated platforms for ESM and ECM missions because of the considerable range increase by antenna elevation *(Fig. 9)*. The higher the transmission frequencies, the higher will be the range increase percentage. An elevated platform in 300 m above ground increases the range of an ELINT-sensor three to four times compared to a ground based sensor.

The payload capacity of KIEBITZ and the possibility to integrate even large antenna configurations around its landing cone structure and its already mentioned characteristic features recommend it as a suitable carrier system for EW-equipment.

Detection of Low-Flying aircraft (Fig. 10)

A radar system on KIEBITZ enables the detection and identification of low-flying aircraft about 1,5 minutes earlier than ground based radar systems. That is equivalent to a dublication of early warning time for anti aircraft weapon systems, what leads to a considerable improvement of their hit probability.

The data transmission from KIEBITZ to the weapon systems is eased by the elevated position of the radio antenna.

The mobility of KIEBITZ and its superior terrain coverage make it a suitable back-up system for destroyed radar sites.

Air intercept radars of lightweight fighters can easily be adapted to KIEBITZ. Their performance characteristics are matching well the radar horizon achieved by KIEBITZ.

Communication (Fig. 11)

An elevated platform can substantially reduce transmission loss. This reduction can provide increased range for communication links, improved signal-to-voice margins or increased bandwidth for higher data rates.

The use of an elevated platform could help to extend the range of RPV's or facilitate communication with nap-of-the-earth flying helicopters or monitoring of remote battlefield sensors. It could be used as back-up system for destroyed radio relays or destroyed long wave antenna stations.

Sea surface surveillance (Fig. 12)

A tethered rotor platform with active or passive sensors can be operated from ships or from the coast. It extends the target detection range to an amount that corresponds with the range of modern ship/ship-missiles, thus eliminating the need for target acquisition by helicopters or airplanes.

6. SCOUTPLATFORM

Besides the development of KIEBITZ as carrier system for far-reaching sensors and transmitters, Dornier looked for technical approaches for elevating optical and electro-optical sensors. The short range of these sensors requires their operation close to FEBA, however their low weight allows a small, relatively inconspicuous carrier system, which can be operated there with good survivability chances.

Our design studies lead to a small, sturdy and easily operable scout system with a compact ground station equipment, which can be integrated into combat vehicles or even on a two-wheel trailer.

It offers the possibility to overcome observation obstacles in the close range as buildings or small woods, that limit ground observation in Central Europe to some hundred meters.

According to its task we called this system SCOUTPLATFORM *(Fig. 13)*. It is a tethered rotorplatform of streightforward design. Its rotor is surrounded by a massive momentum ring which is brought to a high rotational speed by a drive unit in the ground station. It serves as energy store as well as gyro stabilizer. The stored energy is sufficient for a flight time of about one minute in which the rotorplatform climbs to a height of up to 100 m, hovers and is pulled back again to the ground station by its tethering cable. The momentum ring replaces not only a drive motor on the rotor-platform but also an attitude control system for stabilization of the roll and pitch axes. To counteract windforces the rotor can be controlled as a helicopter rotor with command signals being transmitted via signallines in the tethering cable. Azimuth Control is by inclination of flaps at the landing structure, that are blown by the rotor down-wash.

In the center above the rotor plane the sensor payload is attached under a protective plastic cover.

The ground station kit *(Fig. 14)* comprises the rotor drive unit and the cable drum unit, installed in a container which houses the rotorplatform during transport.
During speed build-up of the rotor the platform is geared to the drive unit. The necessary power is delivered by a hydraulic pump flanged to the vehicle engine.
Fig. 15 shows the dependance of flight time on payload and on rotor diameter.

The prototype of the SCOUTPLATFORM has a rotor diameter of 1.2 m. It already performed about 400 successful flights. Its payload capacity of up to 10 kg comprises TV cameras and FLIR cameras with real time picture transmission to a monitor in the ground station via the tethering cable. A less expensive sensor with the advantage of good resolution of a larger field of view would be an instant processing camera. During one flight several pictures can be exposed. One minute after the platform recovering the pictures would be available for evaluation.

An untethered version of the SCOUTPLATFORM could be a cheap and yet efficient carrier for an expendable offboard decoy system for anti ship missile defence. It could be equipped with a jammer and IR-flare to seduce the missile away from the ship to be protected.

7. ELECTRIC ROTORPLATFORM

Some missions for tethered rotorplatforms require a carrier system that is smaller and less expensive than KIEBITZ but of longer flight endurance than the SCOUTPLATFORM

Those missions are mainly:

- Target acquisition and designation for air-launched and surface launched laser designated missiles,

- Over-the-horizon detection of ship radars.

First design studies showed, that a proper drive system for a tethered rotorplatform with a payload capacity of about 30 kg would be an electric motor of high voltage and high frequency because turbine engines are not available in the power class of about 30 kW.

High voltage is desirable because of limited tethering cable cross section for power transmission.

Fig. 16 shows an outline of the proposed rotorplatform. Its rotor is surrounded by a massive ring to ease stabilization of the roll and pitch axes and to increase climb speed by utilizing stored kinetic energy. Torque compensation and yaw control is by control flaps acting in the rotor down-wash.

8. CONCLUSION

It was attempted to give an idea of what tethered rotorplatforms are and how they could be used for military missions. More detailed information could not be given at this place, but the author hopes that he could demonstrate that tethered rotorplatforms are a proper means for increasing the range of sensors and transmitters by overcoming obstacles to line of sight.

Fig. 1 Tethered Rotorplatform of St. Petrôczy and Th. v. Kârmân

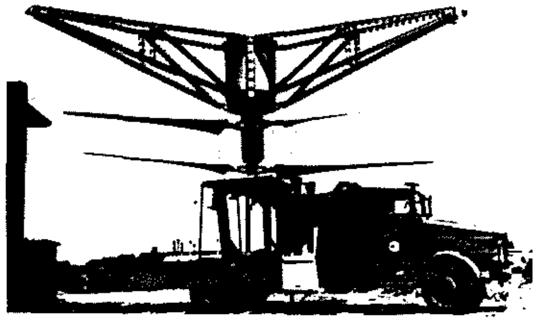

Fig. 2 Tethered Rotorplatform of AEG

Fig. 3 Experimental KIEBITZ

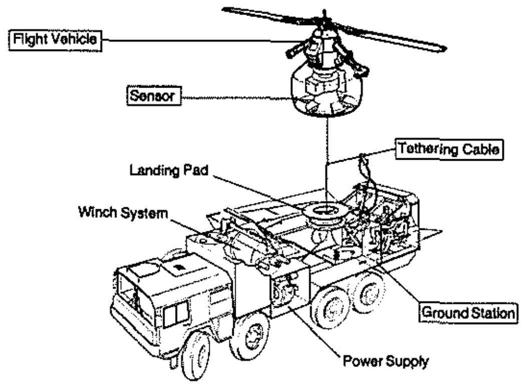

Fig. 4 KIEBITZ

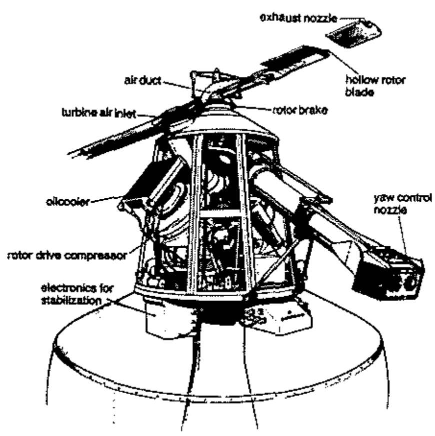

Fig. 5 Rotor Dynamic System

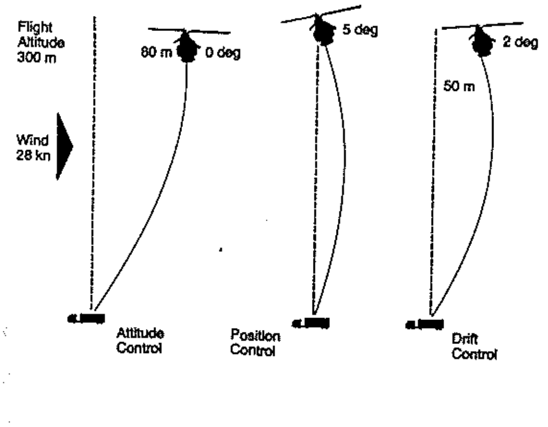

Fig. 6 Control Techniques

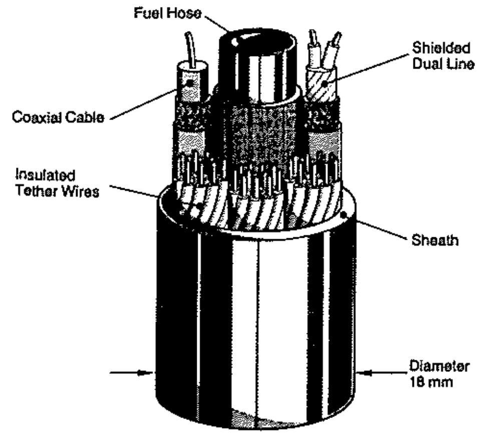

Fig. 7 Tethering Cable

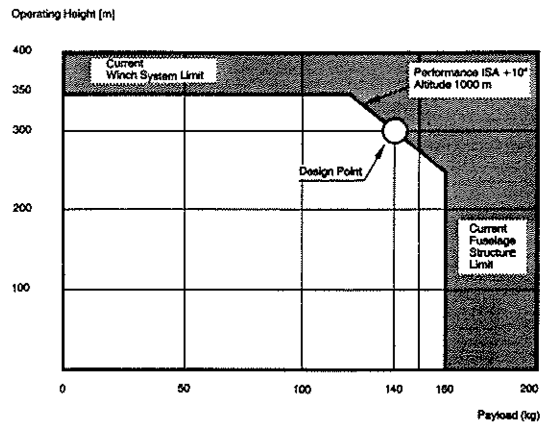

Fig. 8 Performance Limits

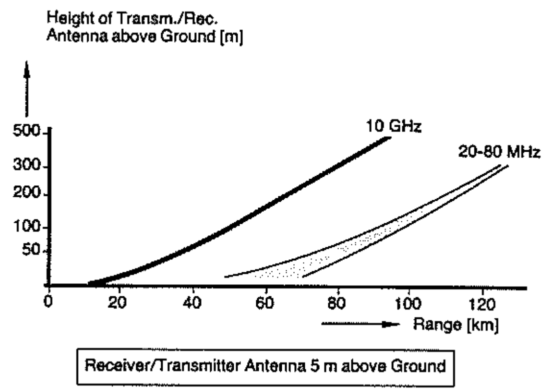

Fig. 9 Influence of Antenna Elevation on Range

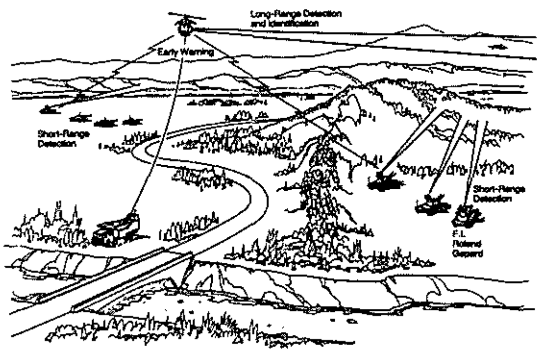

Fig. 10 Detection of Low-Flying aircraft

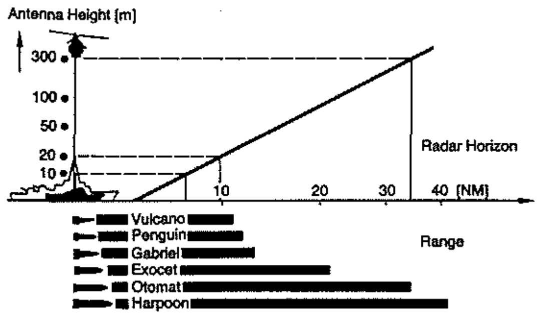

Fig. 12 Range of SS-Missiles and Target Acquisition Radar

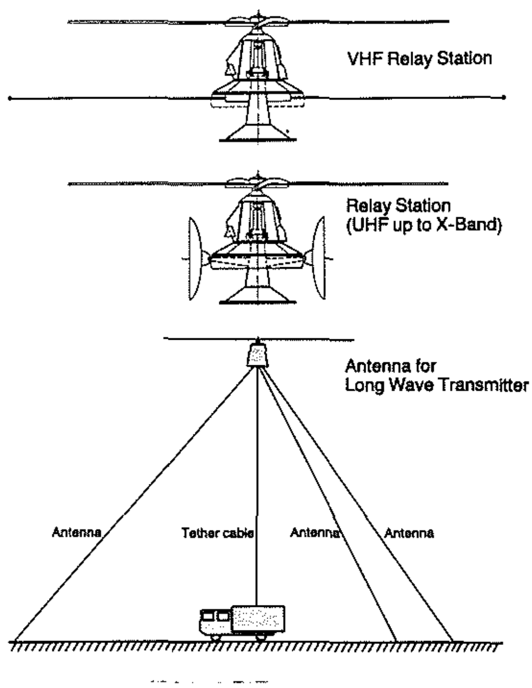

Fig. 11 Communication

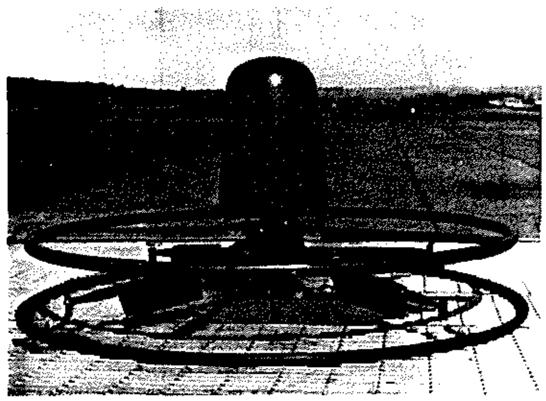

Fig. 13 Scoutplatform

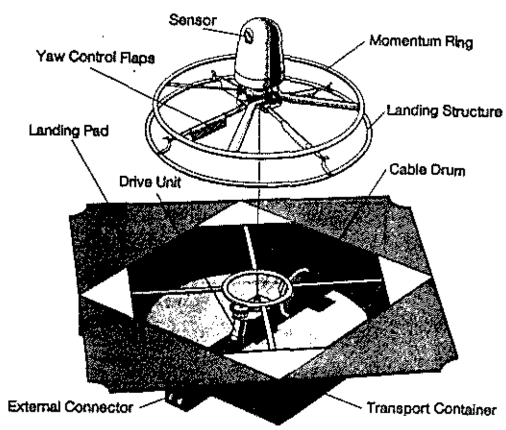

Fig. 14 Scoutplatform

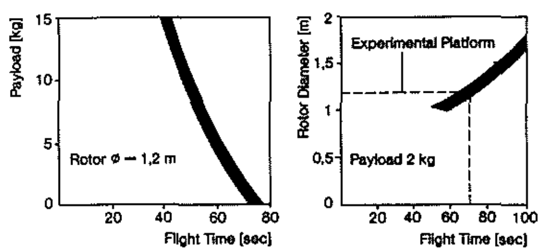

Fig. 15 Scoutplatform Performance

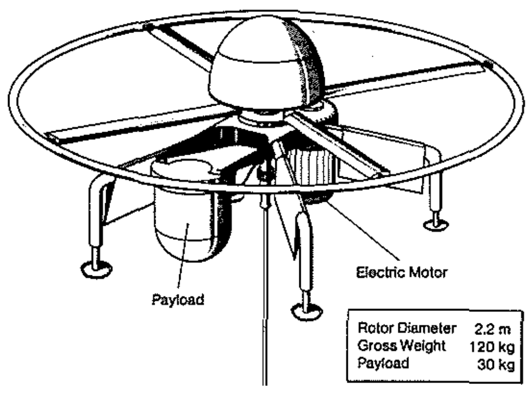

Fig. 16 Electric Rotorplatform