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RADOME TECHNOLOGY

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Abstract

The paper gives a comprehensive view of the manifold field of radome technology. It specifies the parameters influencing the choice of materials and the structural design of advanced aircraft radomes, and it deals with the technical disciplines contributing to radome technology. In this connection, recently developed computational methods, materials and manufacturing techniques, as well as test procedures and test facilities of Dornier are considered. The wide ranging application of radome technology is outlined.

Special attention is directed to spin-off effects. Among others, the strong connection between radome materials and materials for medical implantates and the fruitful interaction between rain erosion testing and shock wave research for medical applications are described.

Introduction

Radomes are used as covers for radar and microwave antennas of aircraft, missiles, ships and land-based installations. In airborne systems, they additionally contribute to a favourable aerodynamic shaping, absorb the aeromechanic loads, and protect the antennas against aerodynamic heating and rain erosion.

Figure 1 gives in a general view some examples of the size, the shape and the location of various radomes in different categories of flying carriers and platforms:

Example 1 shows the disposition of radomes in a commuter aircraft of the type Dornier 228, and that in a version, which has been equipped with special sensors and electromagnetic devices for scientific missions in the frame of an antarctic research programme of the Federal Republic of Germany in the mid eighties.

Example 2 shows the antenna pedestal, 30 feet in diameter and 6 feet thick, of the E-3A airborne warning and control system AWACS. The strut-mounted turnable assembly contains two radomes - one for the surveillance radar and one for the IFF antennas - which are made of multilayer fibreglass sandwich material.

Example 3 illustrates the radomes in a typical combat aircraft covering the nose radar and a great number of transmitter/receiver equipments, which are required for navigation, communication and electronic countermeasures.

Example 4 shows the radar seeker head of supersonic or hypersonic air to ground or ship-ship missiles.

The examples show that there are a large variety of radomes which have, though, one thing in common: they are usually exposed to exceptional impact, airflow and thermal conditions. Thus, aircraft radomes are highly loaded structural components, which have to fulfill special requirements not only with regard to their radaroptical behaviour, but also in respect of their structural properties.

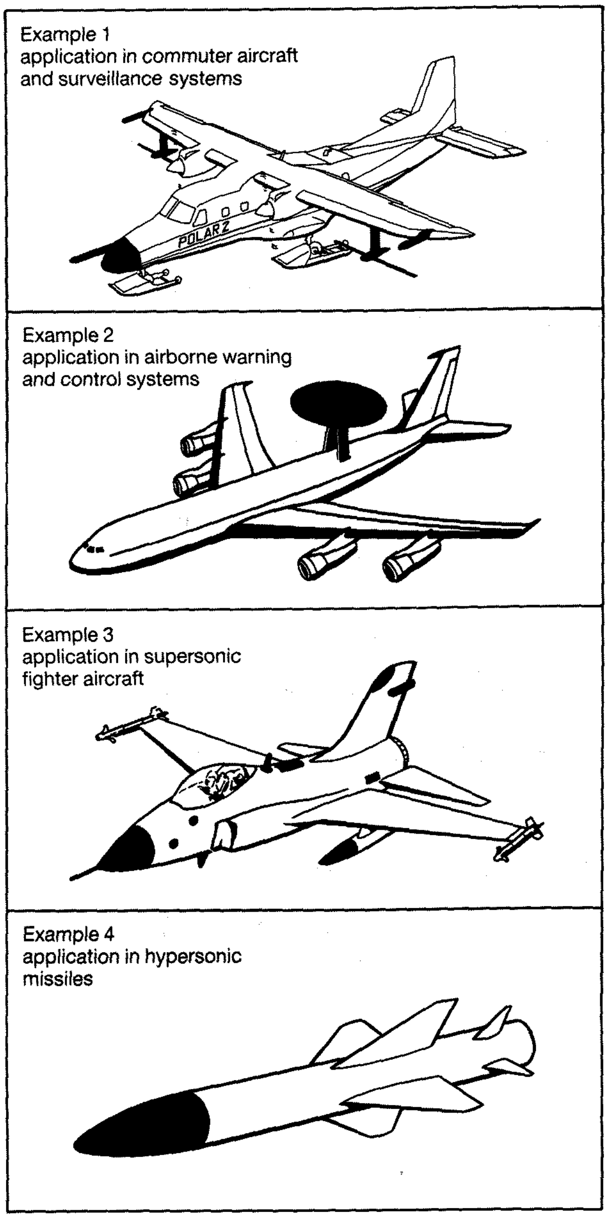

Figure 1. Radome Technology - Examples of application

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Parameters for radome specification

Naturally, both the structural and the radar-optical requirements, which have to be met by airborne radomes, are different according to circumstances: On the one hand, they depend on the electronic device, which has to be protected; on the other hand, they are dependent on the type and mission of the carrier or rather on the resulting working conditions.

Table 1 shows the dominant parameters for the specification of aircraft and missile radomes. As an example, the data for a typical case - the weather radome in a commuter aircraft, compare Figure 1 - are given.

Requirements for aircraft radomes

As to the structural requirements, airborne radomes should have the same properties as primary airframe components such as wing, tail unit, rudders and parts of the fuselage. The desired properties are primarily

- o high strength
- o high stiffness
- o low weight.

In addition, radomes have to fulfill a great number of other, likewise important requirements such as

- o high radar transparency at specified frequencies or frequency ranges
- o high erosion resistance
- o high impact strenght

This means, that radomes are especially complex and challenging structure components, which on the one hand contribute to the load capacity and structural stability of the airframe, but on the other hand exercise an essential influence on the performance and efficiency of the electronic devices.

It is the primary goal of radome technology to supplement the ever improving performance of electronic equipment, mostly as a result of progress made in micro-electronics, by corresponding advances in the development of materials and structure designs as well as manufacturing techniques. Only by this will it be possible to ensure an equivalent performance standard between sensors and sensor/antenna domes and to optimize the overall system consisting of electronic equipment and dome.

Parameters for radome specification	Example
1. Carrier/platform	commuter aircraft Do 228
2. Electronic device which has to be protected	weather radar
3. Location of the electronic device	nose
4. Frequency or frequency range	X-band: 10 GHz band with ~ 1 GHz
5. required radaroptical properties	standard/ not critical
6. operational conditions - air speed - cruising height - flight endurance - stagnation temperature	not critical, typical commuter mission at subsonic speed
7. selected material and structural design	6 mm honeycomb 0,4 mm Epoxy-fibre outer skin polyurethan erosion protecting varnish

Table 1. Parameters for radome specification

Basic requirements for composite components in airframe structures	o high strength o high stiffness o low weight o sufficient fatigue behaviour o sufficient stability o low moisture absorption o appropiate long term behaviour o low electrostatic charge o light protection o suitability for service and repair
Additional requirements for radomes	o high radar transparency in selected frequency ranges o high contour stability o extremely low thickness tolerances o high temperature persistency o high erosion resistance o high impact strength

Table 2. Requirements for aircraft radomes

Synergetic effects

To reach the above mentioned aim of radome technology, several technical disciplines must be mastered and various methods and procedures in researching, developing, manufacturing and testing of radomes have to be combined.

Figure 2 shows on the left side four essential disciplines contributing substantially to radome technology. They cover the fields of

- structural mechanics
- drop impact
- radar optical behaviour
- systems integration.

The right side of Figure 2 indicates the broad spectrum of application in airborne, land- and shipbased systems, which results from the synergetic utilization of the knowledge and the findings in the left mentioned disciplines. The following sections touch upon these disciplines, mentioning some relevant capabilities and test facilities of Dornier.

Structural mechanics

The first important branch of radome technology, in which decisive innovations come off, is the field of structural mechanics. It includes several sections, such as materials research, structure design, computational methods and manufacturing techniques.

As illustrated in Figures 3 and 4, structural mechanics as part of radome technology profit to a high degree by the work on complex subjects in aerospace engineering, mechanical engineering and medical technology. Above all, this applies to the field of composite materials and to computational methods for static and dynamic loads.

At Dornier, the development of composite materials originated from the endeavour to increase aircraft performance by employing lighter materials. The speed brake of the Alpha Jet (Fig. 3a) was the first high-stress series component in European aircraft production made of carbon fibre reinforced plastic. Other important composite components such as rudder, horizontal tail unit and wing have been developed and partially evaluated under real environment conditions on the Alpha Jet.

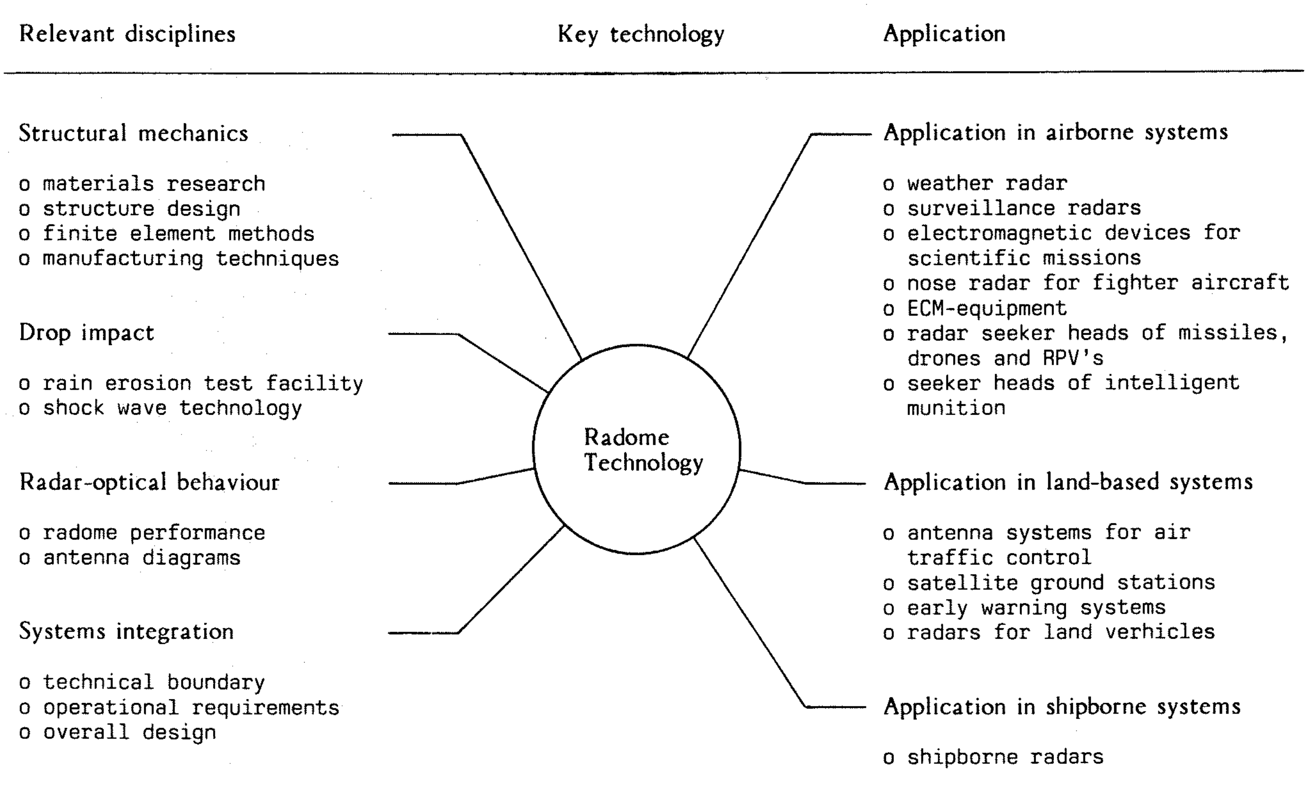
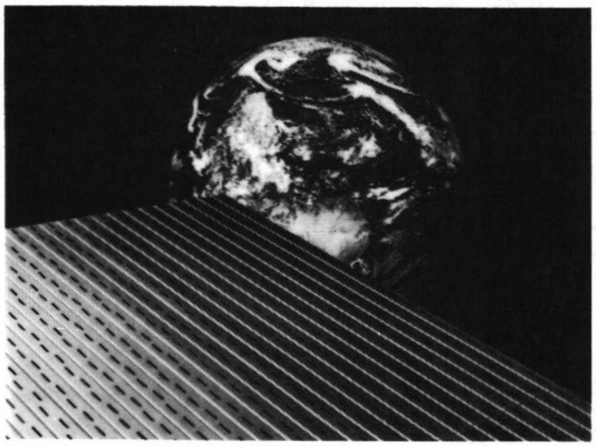


Figure 2. Radome Technology - Relevant disciplines and fields of application

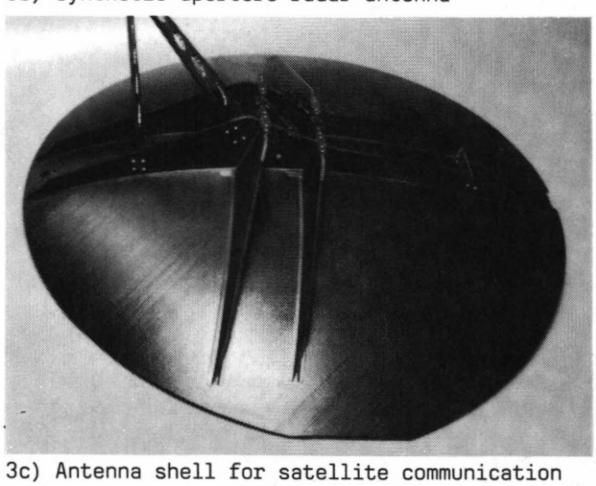
The stringent requirements posed by space flight led to composite materials and production methods of continuously improving quality. Examples for this are the Synthetic Aperture Radar antenna (Fig. 3b) and antenna shells for satellite communication (Fig. 3c). Low weight, thermal stability and high stiffness of carbon fibre reinforced plastics are in both cases used for the construction of high-precision components with extreme contour accuracy. It is evident, that these properties are of great importance for radome technology, too.

For the calculation of statically and dynamically loaded structures, Dornier has developed the COSA- (Computer structure analysis-) program system, which is based on the finite element method (Fig. 4). The integration of the CAD/CAM- (Computer aided design/computer aided manufacturing-) capability is favourable for meeting the actual and future requirements in aerospace, mechanical and medical engineering.

3a) Composite components of the Alpha Jet

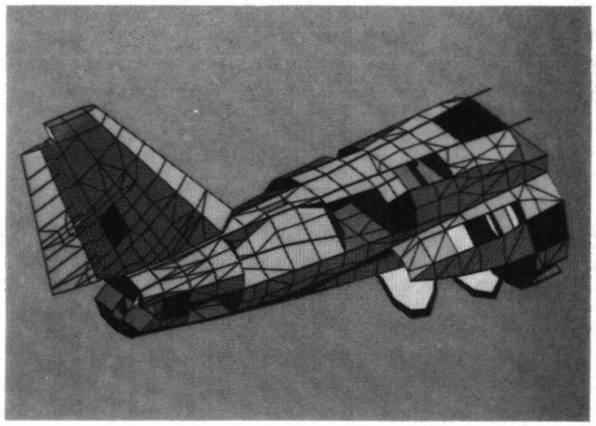


3b) Synthetic aperture radar antenna

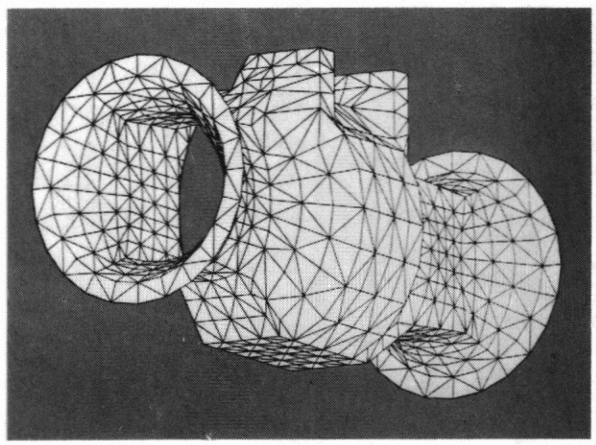


3c) Antenna shell for satellite communication

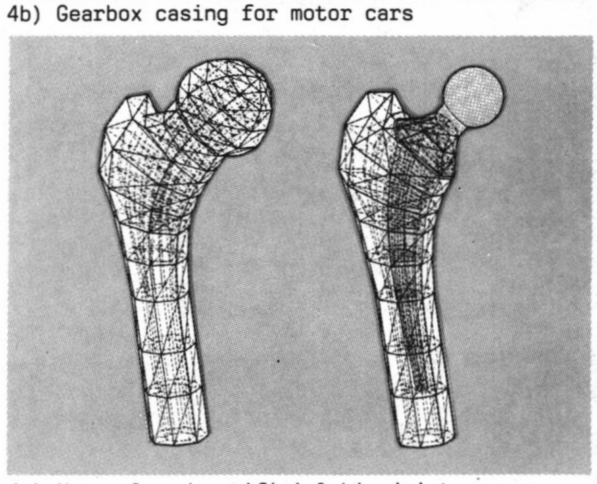
Figure 3. Fibre composites for aerospace components



4a) Rear fuselage of the Alpha Jet



4b) Gearbox casing for motor cars



4c) Natural and artificial hip joints

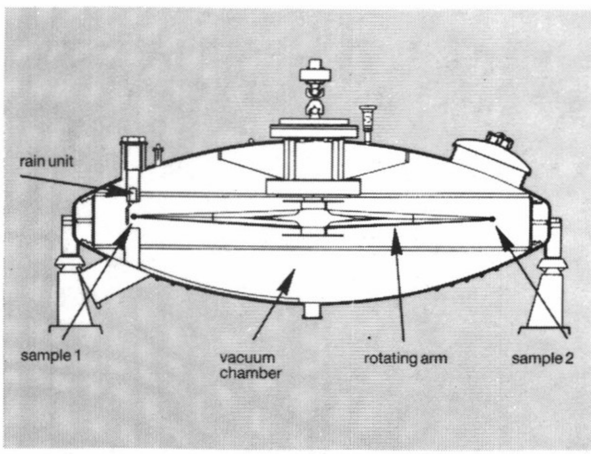
Figure 4. Finite element models for structural analysis

Drop impact, thermal heating

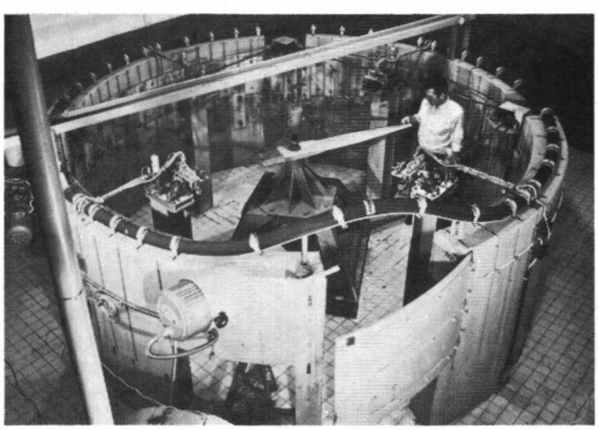
Aircraft radomes are in general high loaded structural components, which are exposed to stagnation point conditions. To guarantee the required radar transparency over the whole service life, in addition to the above mentioned structural strength and contour accuracy, special emphasis has to be laid on the impact behaviour and the resistance to thermal loads.

For testing the resistance of materials against the impact of droplets, ever more powerful test facilities operating to the rotating arm principle have been designed and built by Dornier over the years (Fig. 5). The installation in operation today reaches a maximum speed of 1000 m/s, approximately three times the velocity of sound. It is therefore suited for liquid drop impact investigations in regard of increased mission requirements in aircraft and missiles, such as high speed, long range and all-weather capability.

For high speeds, thermal heating is another important influence parameter. Figure 6 shows a test facility of Dornier for the simulation of thermal loads caused by exhaust gas jets on missile radomes.



5a) Rotating arm principle



5b) General view

Figure 5. Rain erosion test facility of Dornier

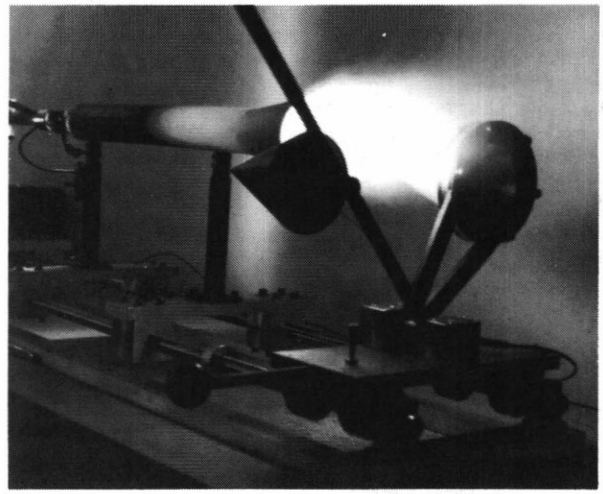


Figure 6. Simulation of thermal load on missile radomes

Radar optical behaviour

In addition to the above mentioned experience in structural mechanics, the design and optimization of radomes requires well-founded theoretical and experimental tools in high frequency technology.

Dornier has developed numerical methods suitable for investigating the radaroptical properties of transparent and absorbing materials or test components and for determining the influence of radomes upon the antennae characteristics.

The establishment of an advanced compact antenna test range makes possible to carry out simulated far field measurements of antennas and domes in the frequency range between 1.7 and 105 GHz. By measuring in a closed indoor facility, disturbing reflections and interference effects are wiped out.

Systems integration

As pointed out in the introductory remarks and illustrated in Table 1, the knowledge of the overall system, consisting of the vehicle and the electronic device, as well as the knowledge of the operating conditions resulting from the mission profile, are likewise important for an optimal radom design. Of course there are very different conditions, according to the application of radomes in airborne, land- or shipbased systems and depending on the fact, wether the carrier platform fulfills civil or military tasks.

An exceptionally interesting outlook to the future emerges in regard of systems integration for flying carriers in form of the so called smart skins technology. By this, the skin of the aircraft will be tailored from the molecular level on up. It will be embedded with fibre optics, with sensors, processors or phased arrays, which will permit the aircraft to sense and communicate in all relevant frequency bands and in any direction from any aircraft altitude. Those aircraft will no more have any pods or domes, because the sensors and antennas are completely integrated in the skin.

Spin off effects

Whilst synergetic effects consist of the application of various technologies or techniques to a new product or process, the term spin off describes the derivation of a new technological application from an existing experience or technology. For both, synergy and spin off, radome technology offers outstanding examples in the research work of Dornier.

It is interesting and likewise satisfying to note, that in regard of spin off effects there are strong interrelations between medical engineering and radome technology. As Figure 7 shows, these interrelations are especially conspicious in materials research and in shock wave technology.

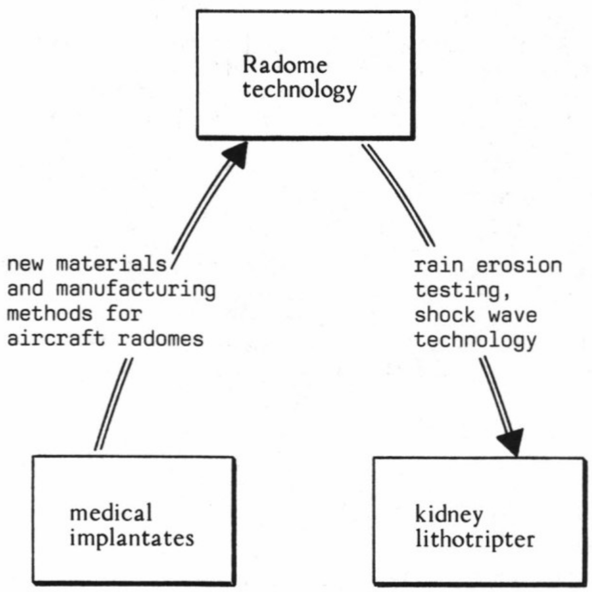


Figure 7. Spin off effects between medical engineering and radome technology

Materials research

Composite materials can be adopted to their intended application by the type, amount and arrangement of fibres used and the selection of the plastic matrix. It is therefore only natural to make medical implants from these materials and, by this, to combine biochemical and biomechanical compatibility.

Dornier has investigated fibre reinforced thermoplastic materials, in particular ultra-high molecular polyethylene (UHMPE) for medical applications. For the processing of fibre-reinforced thermoplastic materials, a film-stacking method was developed by which polymer films and fibre fleeces in variable sequence can be compressed into a pore-free composite material.

UHMPE has excellent dielectric properties. Moreover, its resistance against rain erosion is so high that protective coats can be dispensed with in the case that this material is applied to airframe components. It was therefore logical to use this material for the development of aircraft radomes. Fig. 8 shows a series of UHMPE radomes, which were developed and produced by Dornier for the Alpha Jet.

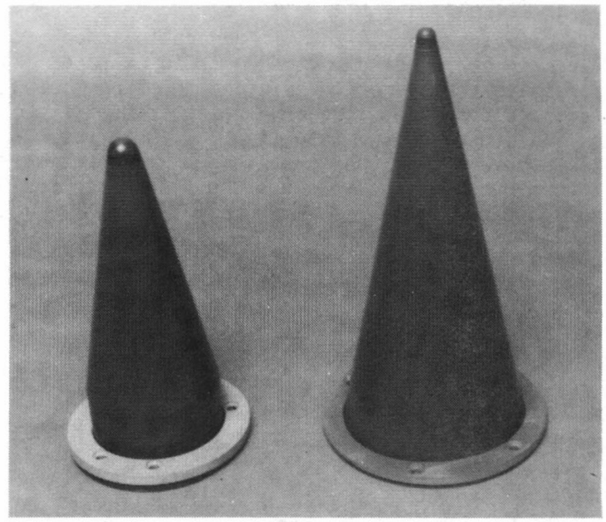


Figure 8. Glassfibre reinforced ultrahigh molecular polyethylene- (UHMPE-) radomes, developed by Dornier for the Alpha Jet

Shock wave technology

In 1962 Dornier got the task for studying the destruction of materials by the impact of droplets. The investigation was triggered by the fact, that domes of missiles, carried along with high speed fighter aircraft, were damaged during the flight through heavy rain (Fig. 9). For a systematic analysis of these damages, the formerly described rain erosion test facility was built.

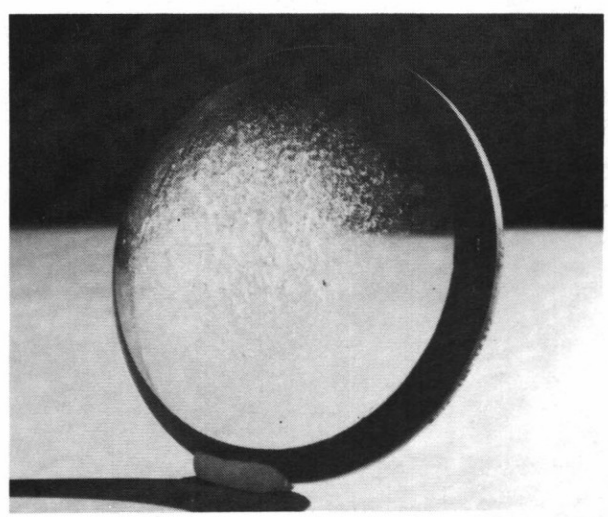


Figure 9. Damage of missile dome by rain erosion

The investigation of drop impact has been at the outset of research into the effects of shock waves on biological systems. The objective was the development of protective measures for the crews of battlefield verhicles. Within the frame work of these activities, the possibility of breaking up kidney- and gallstones by shockwaves was recognized and the idea of nonsurgical disintegration and elimimination of kidney stones was born.

The principle consists in generating shock waves in one focal point of an ellipsoid and focussing these shockwaves via a coupling medium (e.g. water) in the stone to be crushed, situated in the other focal point (Fig. 10). Numerous tests have shown, that the stone disintegrates into minuscule concretions without damaging the surrounding tissue.

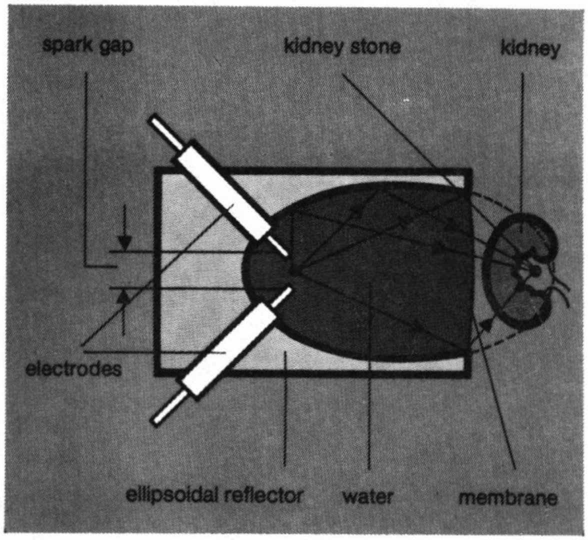


Figure 10. Destroying kidney stones by shock waves: physical principle and mode of operation

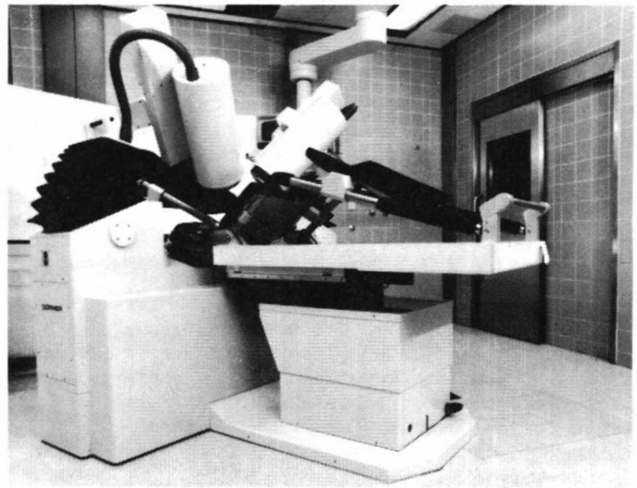


Figure 11. Dornier kidney stone lithotripter

At the beginning of the 70's, the first kidney stones were destroyed by the effect of focussed shock waves. Today, after ten years of research and development, the Dornier kidney stone lithotripter (Fig. 11) is in practical service in many parts of the world. Some hundred thousand patients have been relieved sucessfully from their lithiasis.

The invention and technical realization of the kidney stone lithothripter gives impressive testimony to creative thinking, technological spin off and fruitful interdisciplinary research work between physicians and engineers.