

This document describes the high-level design features of the AIAA Certification by Analysis Uncertainty Qualification Challenge Problem radome antenna¹. Only features are described which are relevant to the Challenge Problem. No structural definition exists for this radome antenna (other than the geometry of the bump or dome), therefore, a “minimum” design has been produced to make possible the calculation of interface loads and reserve factors (RF) or margins of safety (MS). This design is similar to existing radome antenna configurations out there; some design best practices are followed, and some practical assumptions are made for simplicity. Note that the challenge problem *is not a design exercise* for a radome antenna.

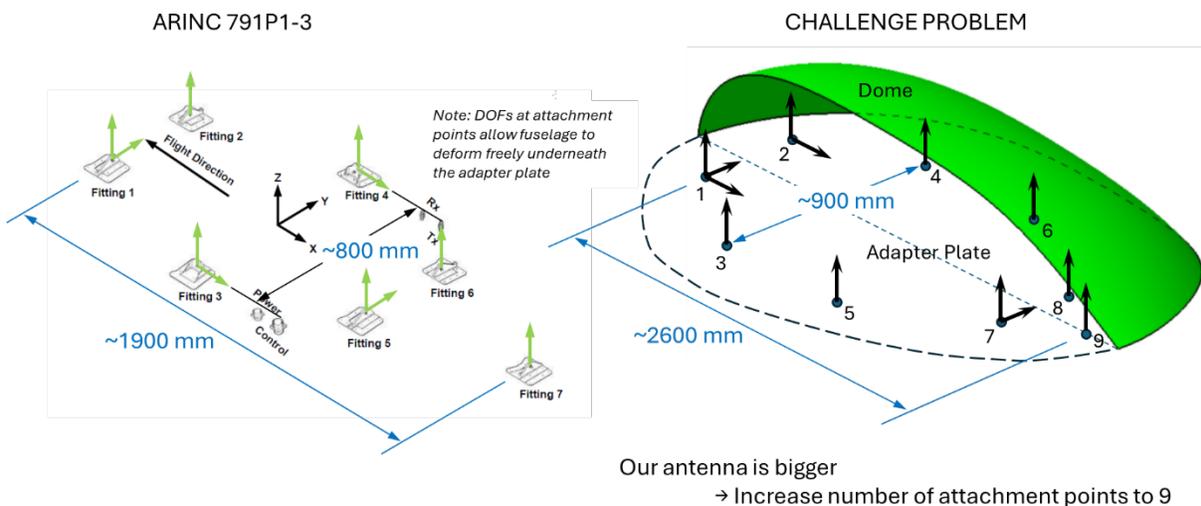


Figure 1 Overview of radome antenna attachment points and associated degrees of freedom

To get an idea of what a physical interface between a radome antenna and fuselage looks like, the reader is referred to the ARINC 791-P3 standard². The footprint of the current antenna is substantially larger than that of the ARINC standard, as can be seen in Figure 1. For this reason, two additional mounting points are added for the present radome antenna, making for a total amount of nine interface points. Special consideration is given to the detailed design of these attachment points: to prevent interference of the adapter plate with the deflections of the fuselage due to pressurization (hoop direction) and body

¹ “Challenge Problem Overview for the Certification by Analysis Uncertainty Quantification Discussion Group,” Philipp Bekemeyer et al., July 2025. (<https://doi.org/10.2514/6.2025-3107>)

² ARINC Characteristic 791-P3, “Mark I Aviation Ku-Band Satellite Communication System, Part 1, Physical Installation and Aircraft Interfaces,” September 2019.

bending (longitudinal direction), appropriate degrees of freedom must be established at each attachment point. These degrees of freedom are indicated by the arrows on the right-hand side in Figure 1, and allow the fuselage to deform freely and independently from the antenna. The location of the nine interface points is given in Figure 2.

Point	x [in]	y [in]
1	-32.5	-8
2	-32.5	8
3	-11.5	-16.1
4	-11.5	16.1
5	11.5	-16.1
6	11.5	16.1
7	37.5	-8
8	37.5	8
9	57.2	0

Location of attachment points:

X = 1694.5 in

Y = 0 in

Figure 2 Location of the interface attachment points.

The bump itself is an aerodynamic fairing and protects the antenna equipment inside from the environment. Both this dome and the antenna equipment are mounted on a so-called adapter plate, which in turn is attached to the fuselage structure. This connection is typically accomplished through pin-joints at the interface locations. These pin joints comprise three distinct parts: the male lug (referred to as “the lug”), the clevis (female lug), and the pin. The lugs in all the attachment points are located on the fuselage as shown in the left-hand side of Figure 1, while the clevis portions of the joints appear on the adapter plate. (Note that, in practice, these joints will be designed for ease of installation and removal). Most satcom antennas are similar when it comes to the components described above, which are identified in Figure 2.

To receive the adapter plate, the fuselage is provisioned with (male) lugs that mate with the (female) clevises on the adapter plate. The addition of these lugs requires local alterations and reinforcement of the fuselage structure to carry the additional loading from the radome assembly. Holes need to be cut in the fuselage local to the satcom to route electrical wiring required for the antenna equipment to function; these cut-outs are usually reinforced with doubler plates around the holes. However, consideration of the fuselage structure details is out of scope for the present Challenge Problem.

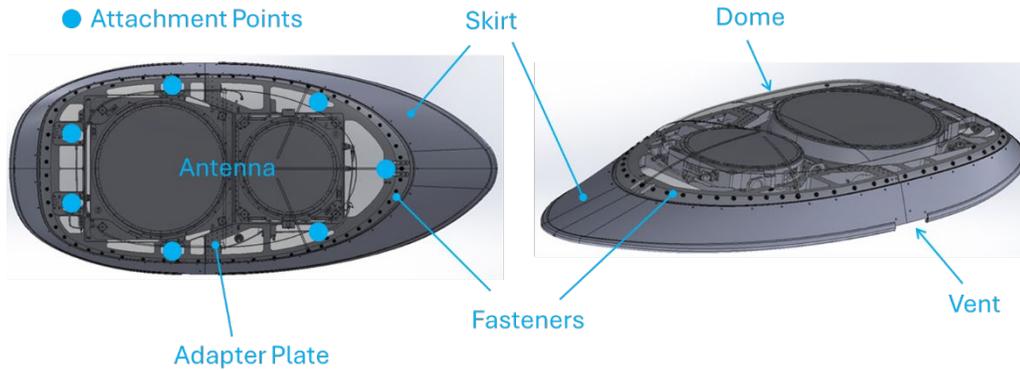


Figure 3 A typical satcom antenna and its main parts.

In the following the individual elements of the radome assembly will be discussed in more detail.

Dome

The dome is fabricated from quartz fiber-cyanate ester composite fabric material. (Quartz has low dielectric properties which are favorable for signal transmittal). The lay-up has been chosen to be quasi-isotropic (meaning an equal number of fibers in the 0-, +45-, -45-, and 90-degree directions) and consists of 32 plies, each 0.011 in (0.279 mm) thick, totaling a nominal laminate thickness of 0.352 in (8.94 mm). The material properties for a single ply are given as follows:

$$E_1 = 3.25 \text{ msi (22408 MPa)}$$

$$E_2 = 3.25 \text{ msi (22408 MPa)}$$

$$G_{12} = 0.6 \text{ msi (4137 MPa)}$$

$$\nu_{12} = 0.15$$

$$t_{\text{ply}} = 0.011 \text{ in (0.279 mm)}$$

The nominal material properties for the 32-ply quasi-isotropic laminate are as follows:

$$E_x = 2.64 \text{ msi (18202 MPa)}$$

$$E_y = 2.64 \text{ msi (18202 MPa)}$$

$$G_{xy} = 1.01 \text{ msi (6964 MPa)}$$

Lay-up: $[(0/45/-45/90/90/-45/45/0)_2]_s$

Adapter Plate

The material used for the adapter plate is typically a high-strength aluminum alloy. For the challenge problem, the assumption is that the adapter plate is integrally machined from 7050-T7451 (AMS 4050) plate material with a stock thickness of 2-3 inches. Properties and design values for this material can be found in MMPDS³. The adapter plate features a base with integral vertical “blade” stiffeners, as shown in Figure 3. Real estate is provided at nine locations to accommodate the hardware required for the pin connections. It is immaterial to the current problem whether this hardware (i.e., the clevises) is machined integral to the plate or attached separately. Other features are a cutout or opening to accommodate wiring that runs from the antenna equipment into the fuselage (and results in some weight reduction as well), and provisions to mount the hardware associated with the antenna.

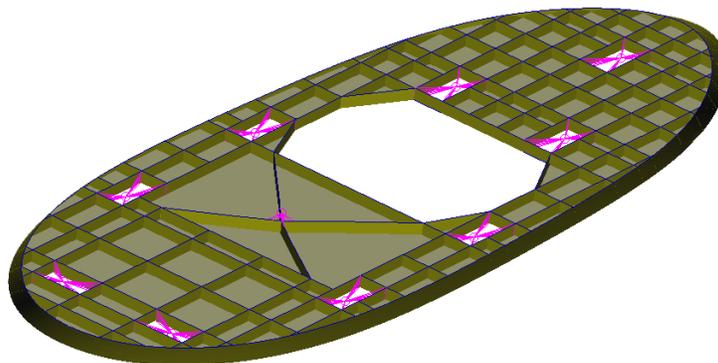


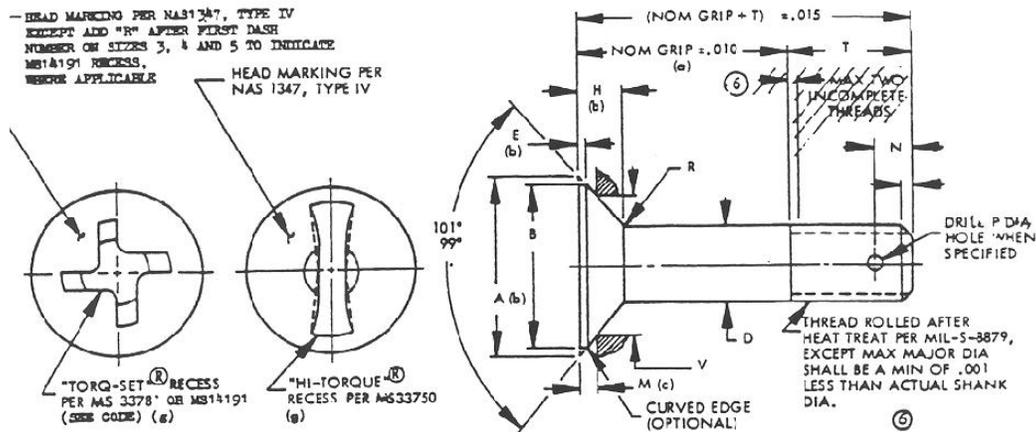
Figure 4 Grid-stiffened design of the adapter plate.

Dome-Adapter Plate Joint

It is important that the dome is easily removable from the adapter plate for servicing the antenna equipment and inspecting the condition of the structure and attachments to the fuselage. Typically, countersunk removable fasteners are used for this purpose which are installable from one side of the joint. For the present antenna the assumption is that NAS1580 bolts are used with a diameter of 0.25 inch (6.35 mm).

³ MMPDS-2025, Volume 1: Conventional Materials and Joint Allowables, Batelle, 2025.

NAS1580 bolt:



Skirt

The skirt serves as an aerodynamic fairing between the adapter plate and the fuselage. As a simplification in the challenge problem, the skirt is assumed to be of the same construction as the dome.

Venting openings are typically provided on the skirt to allow some mitigation of the cavity pressure differential due to changes in altitude. This internal pressure is expected to (eventually) equalize with the external pressure at the vent locations. The skirt is assumed to have two vents—one on each side of the radome—located at the mid-length position as illustrated in Figure 4.

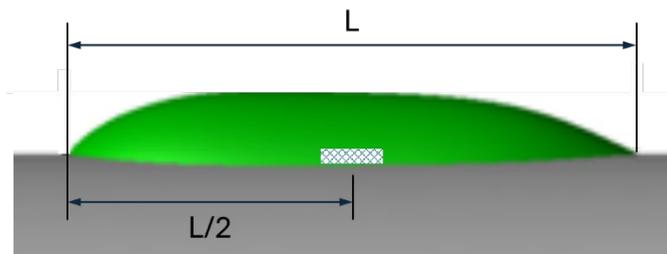


Figure 5 Location of vents in the skirt of the radome (one each on LHS and RHS).

Pin Joints

The design details of the pin joints that form the fuselage attachment are out of scope for the current Challenge Problem. What makes these joints more complicated are the

various degrees of freedom that must be left unrestrained. In a standard lug-clevis pin joint, generally the only degree of freedom not restrained is the rotation about the pin axis. As can be observed in Figure 3, most of the interface points only restrain translation in the upward (z) direction. A design like that requires the joint to have the ability to “slip” in the forward-aft (x) and lateral (y) directions.

A spherical bearing is utilized in the lugs so that there is unconstrained rotation about all three axes. The hole in the fitting must be large enough to accommodate this spherical bearing (which come in standard sizes); therefore, the diameter of the lug bore is considerably larger than the pin diameter. Similarly, the clevis bores are also larger than the pin diameter, in this case to accommodate separate bushings. Slip parallel to the pin is achieved through accommodating gap values, allowing the spherical bearing and associated fitting to slide along the pin.

An illustration of what is considered a typical basic pin joint configuration for the purpose of the current Challenge Problem is presented in Figure 5. It comes with the disclaimer, though, that additional means are required to provide slip in perpendiculars directions for the interface joints that require this functionality. However, it is not elaborated on how these slip designs may be achieved.

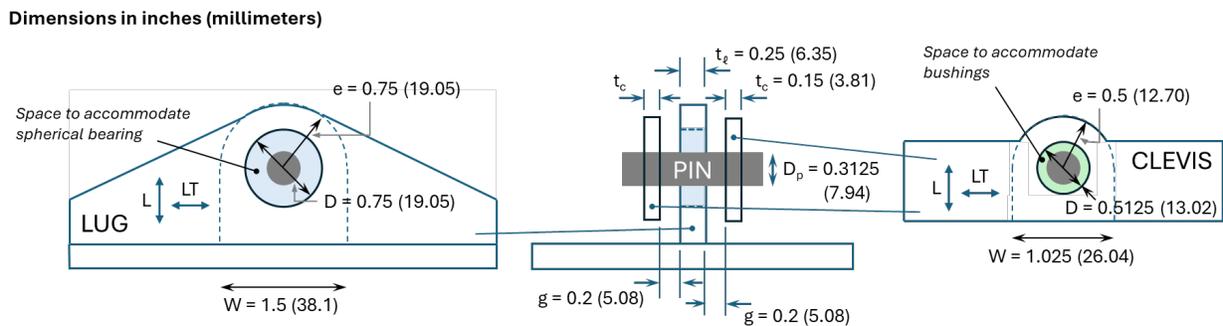


Figure 6 Basic lug-clevis design configuration assumed in the Challenge Problem

It is assumed that the lugs are made from the same material as the adapter plate, which is 7050-T7451 plate material with a 2-3 inch stock thickness. The grain direction orientation relative to the lug and clevis parts is indicated in Figure 4 (“L” represents the rolling direction of the plate, “LT” the transverse direction). The bushings utilized for the clevises are assumed to be made of a copper-nickel-zinc alloy; the pins are assumed to be made of CRES 15-5PH high-strength steel.

Bushings:	$F_{cy} = 60$ ksi (414 MPa)	...	<i>compressive yield strength</i>
Pins:	$F_{su} = 81$ ksi (558 MPa)	...	<i>ultimate shear strength</i>
	$F_{tu} = 140$ ksi (965 MPa)	...	<i>ultimate tensile strength</i>