NOSE FAIRINGS ON ROCKETS AND BALLISTIC MISSILES

The front end of a rocket is usually a structure, known as a *fairing* or *shroud*, that serves to protect the satellite being launched from the external aerodynamic loads, vibration, noise, temperature extremes, dirt, dust, rain, snow, and micrometeorites that may be encountered as the satellite is launched and accelerates through the atmosphere into space.

The design of a fairing is governed by a myriad of factors including its weight, contribution to overall vehicle drag, structural strength, cost, and the size and shape of satellites it is to enclose.

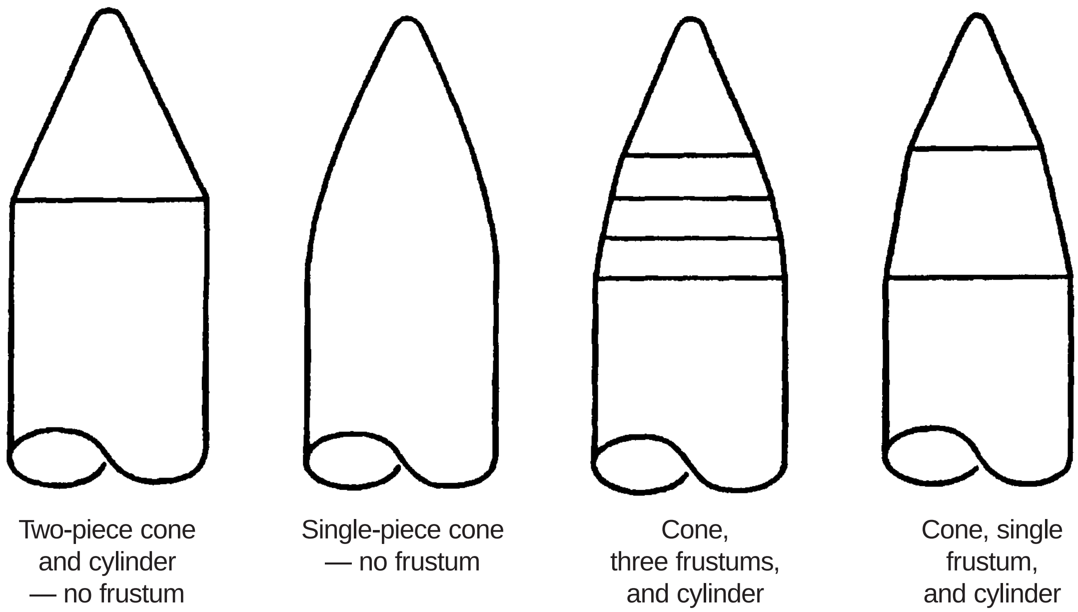
The relationship between fairing shape and just two of these factors — weight and drag — for a class of fairings of simple geometrical shape is shown above.

The question of whether minimum weight or minimum drag should be given greater emphasis depends on the details of the launch. If the fairing can be dropped early in the flight, low drag is more important. If satellite payload protection is needed through a large part of the launch trajectory, then the weight of the fairing becomes more significant in launch performance.

Given a specific fairing design, and a specific launch trajectory, the weight-drag tradeoff influences the altitude at which the satellite is separated from the rocket.

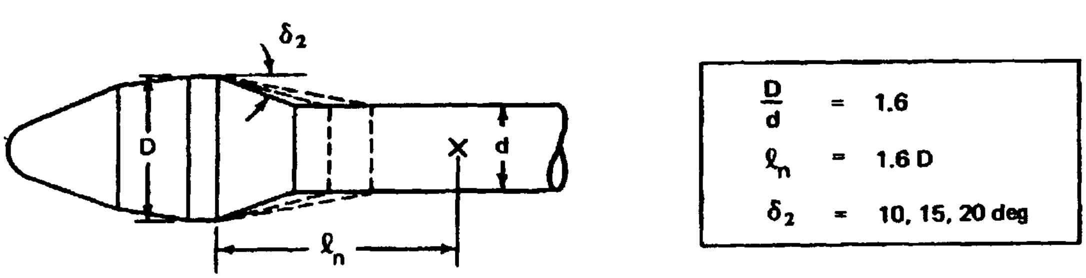
Cost and ease of manufacturing can also be factors in shaping fairings. The following graphic shows the evolution of fairings for the NASA Saturn rockets. The evolution was toward a single frustum/cone, and it occured on the basis of compromises of effects on vehicle performance with volume enclosed, fairing manufacturability, and cost.

U.S. Fairing Development Over Time



Fairings developed for NASA's Saturn rockets evolved toward a single frustum/cone as a compromise among such factors as the effects on vehicle performance, manufacturability, and cost.

Overshadowing these factors, however, is the requirement that the fairing be shaped to enclose the payload being launched. For large payloads, such as the current generation of communication satellites, the satellite containment requirement often leads to the use of hammerhead fairings (see illustration below) in which the maximum diameter of the fairing exceeds the diameter of the uppermost stage of the rocket. This type of fairing is subject to severe buffeting loads as it traverses the transonic speed region due to unstable aerodynamic flow separation and shock waves in the transonic region.



For large payloads such as today's communication satellites, hammerhead fairings are often used. The maximum diameter of the fairing exceeds the diameter of the uppermost stage of the launch rocket, and is subject to severe buffeting loads as it traverses transonic speeds.

Land-based ballistic missiles with single warheads usually do not have fairings (or shrouds, as such components are more often called in missile terminology) covering the warhead. However, ballistic missiles with multiple reentry vehicles (MRVs) and multiple independent reentry vehicles (MIRVs) usually do have shrouds, although with advanced nuclear weapon design, the density of the payload is high and the volumes to be enclosed are usually smaller than for communication satellites. Consequently, hammerhead designs do not seem to have been used for the shrouds on ballistic missile systems carrying multiple warheads.

However, it should not be assumed that single warhead missiles never use fairings, while multiple warhead missiles always use them. The U.S. Minuteman II ICBM faired its single, relatively blunt reentry vehicle in order to present a lower radar cross section at a time when a widely-deployed Soviet ABM system seemed to be in the offing. Moreover, this fairing was not shed until well into atmospheric reentry.

Another possible use of fairings would be to protect road-mobile missiles from the rigors of the environments to which they would be exposed, although covers that would be discarded before launch would be more likely.

Finally, in some cases, a shroud or partial shroud in the form of a nose cap might be used for drag reduction in the case of a blunt reentry vehicle. Again, the likelihood of hammerhead fairings being used for this purpose is not great.

In the case of the U.S. Trident submarine-launched ballistic missile, because of the limited length of the launch tubes, the shroud is blunt on launch, but a device known as an "aerospike" is extended forward from the front end to reduce drag in flight through the atmosphere.

Thus, the most likely PRC ballistic missile use of fairings would be on missiles equipped with MRVs or MIRVs, or on a submarine-launched missile. If the United States goes forward with a National Missile Defense program, the motivation to employ either MRVs or MIRVs may become compelling for the PRC. In the same vein, the incentives to employ various types of penetration aids (chaff, balloons, decoys, distributed jammers, etc.) will increase, and shrouds may be used to protect them and their deployment mechanisms.

Although the detailed configuration of ballistic missile fairings may be substantially different from the fairings used on rockets, the methods for determining quasi-steady as well as vibratory and acoustic noise-generated flight loads, and for designing the structure to resist these loads, would be the same.

Thus, the PRC experience and knowledge of the aerodynamic and other loading conditions and environments on rocket fairings, and the structural design process taking these conditions into account, would stand them in good stead in developing fairings (or shrouds) for ballistic missiles.

While the basic theories and experimental methods for determining flight loads and environmental conditions on rockets are in the public domain, the successful application of these theories and methods in design often requires know-how and engineering judgment derived from experience. Thus, for example, a recent text (*Space Vehicle Mechanics, Elements of Successful Design,* Peter L. Conley, Editor, John Wiley & Sons, Inc., New York, 1998, pg. 589), in discussing the qualification factors to which rocket components are to be designed and tested, cites some differences between the military and NASA standards, and then goes on to say:

> *MIL-STD 1540 and NASA-STD 7001 both state that the document should be tailored by the user to fit a particular space vehicle program. Even these definitive documents leave room for debate.*