

CPE 625 – Fundamentals of Systems Engineering

Individual Project – Priya Rao

System:

Motorsport Racing (Formula 1)

Problem:

Safety of Drivers

Need:

The main need is protection of drivers. Drivers need protection from large pieces of debris or another car from falling on the driver's head. Protecting the drivers from hitting their heads if the vehicle flips upside down during a collision.

Not till the late 1960's, soon after the world fell in love with racing in the late 1800s, the third time winner of Formula One, the champion Jackie Stewart spoke about the drivers who died in the car race previously. He had witnessed around 57 racing deaths between 1963 and 1973. He also said and calculated that if a driver had competed for five years, there were about two-out-of-three chances of getting killed in the crash. From 1970 to 2000, a database of driver deaths documented approximately 70 drivers in open-wheel, sports car, stock, sprint, modified and dragster racing died after hitting concrete walls, tires, guardrails and fences. The need is to increase the safety of the cockpit and hence the driver.

Overview

Some of the major reasons for the race car crashes and driver deaths in Formula One - crash barriers, which were one of the most important and essential safety devices on the racing track were made up of poor quality. Also Armco guardrails of steel which pierced cars like knives were replaced or cushioned by tires, that scattered and later on rebounded into traffic, even after a minor bump caused the car to flip over. Catches, fences and concrete walls also caused race car crashes.

Improvements Implemented for the safety of driver or Steps taken to increase drivers safety-

Improvements were made in emergency services. Seat belts, helmets, run-off areas which were non-existent came into existence. Crash barriers were constructed. Straw bales, dirt mounds, fences or cement retaining walls were built. Drivers' survival increased when a buffer was provided. Buffer absorbs the energy caused from the impact and releases it later. Enough safe deceleration was provided to avoid hitting the hard walls. There should be two or three rows of buffer barriers in the areas where life threatening crashes have occurred before. Concrete walls or Armco or a combination of the two have to be built where there are treacherous turns. The The buffer barriers should adjust to different configurations, adapt to any layout, curve, corners or angle. Buffer barriers must be able to bear high speed hits which causes less deformation and results in less damage to cars and the drivers.

Active and Passive stakeholders of the system:

- Drivers
- Manufacturers
- Maintainers

Passive Stakeholders:

- Fans
- Government (governments of countries hosting races each year)
- Sponsors

Four Important Stakeholders of the system:

When you consider Formula One in particular or any kind of sport in general, it is fully a joint venture. When you go more in detail, all the stakeholders/parties involved have the same common interest in looking at the safety of the drivers, protecting the driver's head from any flying debris or any other obstacle which comes in the way of the driver during the race. It doesn't matter where the brands are investing money, all that matters is the safety of the drivers during the race. Accidents happen in the race because of different reasons and there are safety measures and precautions mentioned to it. There are 3 main stakeholders for the system and they are drivers, manufacturers and maintainers. Each and every stakeholder would function differently, but they all have to work together to provide safety for drivers. Work should be completed in a group to make sure that each and every stakeholder provides adequate amount of safety to drivers and protect the driver's head from flying debris, runaway wheel whenever there is a collision and a race car flip over.

Drivers:

Safety of drivers is of utmost importance in Formula one. There are three main reasons for the accidents to happen. 1.flying debris 2.runaway/loose wheel 3.crossover crash in which one car rides over another. There are many incidents where flying debris and runaway wheel have caused death of the drivers. It's the clear and present danger in Formula one. There are some of the drivers who have lost their lives because of these accidents. Accidents which have been caused by flying debris and runaway wheels have been described below.

Lets consider the runaway wheel. Because of the collision, a wheel gets detached from the car, even though wheel tethers are fitted to prevent such accidents. When there is extreme collision, tethers serve its purpose especially in a fairly common scenario of a car dragging along a crash barrier. Here is an example of a seven time former world champion Michael Schumacher who died on the spot when his car went out of control, hit the barriers, bounded off and then slid across the track before coming to rest. Colliding with the barriers was not a real threat of harm to the Formula one race driver, the run-away wheel was the most deadly threat to him and the others. The tethers are not attached to the rotating wheel, tethers are mounted on to the hub. When the nut holding the mounted wheel and hub come off, the wheel is completely free.

The next factor which caused the death of the driver is because of the flying debris, a crossover crash in which one car rides up over another which is extremely hazardous. There is another formula one race driver called Felipe Massa who was struck by stray debris and injured by a rare suspension spring(flying debris) that has come adrift from Rubens Barrichello's car during qualifying for the 2009 Hungarian F1 GP.

While on one hand a detached wheel is extremely dangerous, a detached wheel being struck to the driver's head is highly fatal. In 2009, F2 driver Henry Surtees was killed by a detached wheel that struck his head during a race at Brands Hatch.

For the above accidents caused by the flying debris, runaway/loose wheel and crossover crash in which one car rides over another, safety measures have been given by the manufacturers and maintainers below.

Manufacturers:

The CP Tech is one of the main manufacturers of Formula one. It was the first supplier to produce the new HALO cockpit protection system for formula one. It was designed by Mercedes team and approved by FIA. A new HALO cockpit protection system was introduced to protect the drivers' head from flying debris and runaway wheels. All the HALO parts are manufactured by CP Tech.

CP Tech is a provider of ultra-strong components and solution for the automotive and motorsport industry. CP Tech successfully achieved the stringent requirements prescribed by the FIA standard.

Drivers' safety has always been a primary concern for FIA. In 2011, FIA institute launched a research project to develop advanced frontal protection to protect the heads of the drivers. The HALO device is a concept that was developed by Mercedes jointly with the FIA to deflect flying objects and debris, such as loose/runaway wheel away from the drivers' head. The HALO concept was developed by Mercedes team and involves a sloped centre-line fin with a roll bar that sits above the driver's head. During cockpit protection tests, if told AUTO, the HALO device would protect the driver from all angles if a loose wheel was to strike a car. Although the structure is very close to the driver's helmet to provide protection from all angles, it will still prevent the flying debris or a flying wheel from hitting the helmet.

To deflect flying objects and debris-

The Additional Frontal Protection (AFP) would be placed towards the front of the car. It's close to where the nosecone attaches to the front of the chassis, to deflect objects moving into the path of a driver.

To deflect a wheel away from the driver-

The centre line roll hoop consists of three curved round section bars. It passes over the driver's head from the existing roll hoop on the car itself to the front of the chassis near where the nose is attached. The bars are designed to flex and deflect a wheel away from the driver.

To protect from intrusion from above and flying debris-

Many researches were made to see how the driver had to be provided with safety by Formula One. To protect them from intrusion from above and flying debris, the car was fitted with a smaller screen ahead of the cockpit and an additional safety hoop above the driver's head. This was to protect the driver's head from an intrusion from above and from foreign objects from outside the car. It could protect the drivers' head from the front but not from oblique angles.

Statistically when you put the visor in front of the driver you are going to increase his protection against small debris coming to hit him.

About CP Tech-

CP Tech provided the HALO parts. CP Tech is a provider of ultra-strong components and safety equipments to drivers. It provides solutions for the automotive and motorsport industry and provides protection to race drivers in various ways. During the development, CP Tech successfully achieved the stringent requirements prescribed by the FIA standard. For CP Tech driver's safety has always been a primary concern. There were many accidents caused because of the runaway wheels, flying debris and crosscrash over crash in which one car rides over another car. CP Tech developed the advanced frontal protection for the protection of heads of drivers. CP Tech focusses on innovative self-developed products, engineering services, high performance components and gives complete solutions for the automotive, motorsport industries. CP Tech focusses on the development of new vehicle and mobility concepts, shaped by global trends such as e-mobility, light weight construction, connectivity, sustainability and autonomous driving. These concepts can be used while designing and providing safety to a formula one race car.

Maintainers:

Federation International de l'Automobile is commonly known as FIA. It is a non-profit organization established as the Association International des Automobile Clubs Reconnus (AIACR) on June 20, 1964. FIA is the main maintainer of Formula one. FIA is mostly known as the governing body for motorsport racing events. FIA is headquartered at 8, Place de la Concorde, Paris. FIA consists of 213 national member organizations in 125 countries world-wide.

The main safety feature designed by FIA is the HALO. HALO was designed to prevent the intrusion of foreign objects into the car. Anti-intrusion side panels is the safety feature to prevent intrusion from the foreign objects into the car. The HALO Frontal Cockpit Protection (FCP) was introduced to protect the driver from other foreign objects like the flying debris and the runaway wheel. To prevent any sort of penetration into the car, a Front Anti Intrusion Panel (FAIP) was attached ahead of the front bulhead to prevent penetration into the car.

Debris Containment-

Large sections of car debris are being shed from the car. The wheel assemblies are retained with the car with the three upto Xylon tether per wheel. Because of this, the flying wheel coming off onto the track or into public enclosure has massively reduced. Its reduced because of the introduction of wheel tethers.

FIA's safety measures which helps to prevent crossover crash where one car rides over another car because of flipping-

The main criticism of the current track designs is the tarmac run off areas. The gravel run off areas prevent flipping. This should lower the risk of overtaking and the car can rejoin the track after a failed overtaking attempt. A new high grip surfaces are being introduced which helps the car to slow down.

FIA announced Formula one cars would be fitted with a new head protection structure known as HALO.

Introduction to HALO

The HALO is a recent safety addition to Formula one. HALO is designed to be the first point of contact for an incoming object, instead of the driver's head. Its very easy for drivers to create a shower of debris with the slightest of mistakes. External forces take control, like a faulty part, flying debris, loose wheel which can strike the driver's head. HALO is a wishbone-shaped piece of metal that circles the driver's head protecting the driver's head from debris and from any sort of obstacles caused by collisions. HALO circles the cockpit of a single-seater race car. The HALO connects in three different places, it connects in front of the cockpit, and just behind it on either side of a driver's shoulders.

How HALO protects drivers?

1. It prevents another car or large pieces of debris from falling on a driver's head after a collision.

2. The front point of the HALO deflects debris that would hit the driver in the face or helmet if it bounces off the front of the nose cone.
 3. It prevents drivers from hitting their heads when the vehicle flips upside down during a collision.
- All of the above are critical, lifesaving functions that keep drivers safe.

Mercedes team were the first to offer up a HALO design with the Red Bull's advanced technologies. A transparent aeroscreen surrounding the cockpit was introduced by the Mercedes team. FIA decided to follow the concept developed by Mercedes. Mercedes developed the concept of "shield" a transparent polyvinyl chloride screen used to protect the driver's face from flying debris and the runaway wheel. HALO would be a new safety equipment especially for the drivers who flip over during a race. Since the HALO could keep the car elevated upside down, it could be essential in providing space between the drivers and the road when a car flips due to an accident, and helps them to escape from the vehicle easily.

Key Success Criteria:

- Increase safety of drivers in cockpit
- Decrease number and threat of accidents

Concept Designs:

(a) Closed Roof:

Closing the cockpits of Formula 1 cars (or indeed Indycars) would have a number of consequences that would need to be considered. Visibility is a key concern and reducing it can clearly lead to accidents. One implication of introducing a fully enclosed cockpit, or indeed the almost fully enclosed concepts is a resulting reduction in overall drag and better airflow to the rear wing.

(b) Halo Device:

The Halo system is incredibly strong, the strongest element on the car in fact, capable of bearing forces up to fifteen times the weight of the car itself. This strength enables it to handle large impactors such as a wheel, large body panel, or wing with ease, and provides additional rollover protection. But at the same time, it is not useful against small impactors and reduces aerodynamicity which decreases the pace of the car.

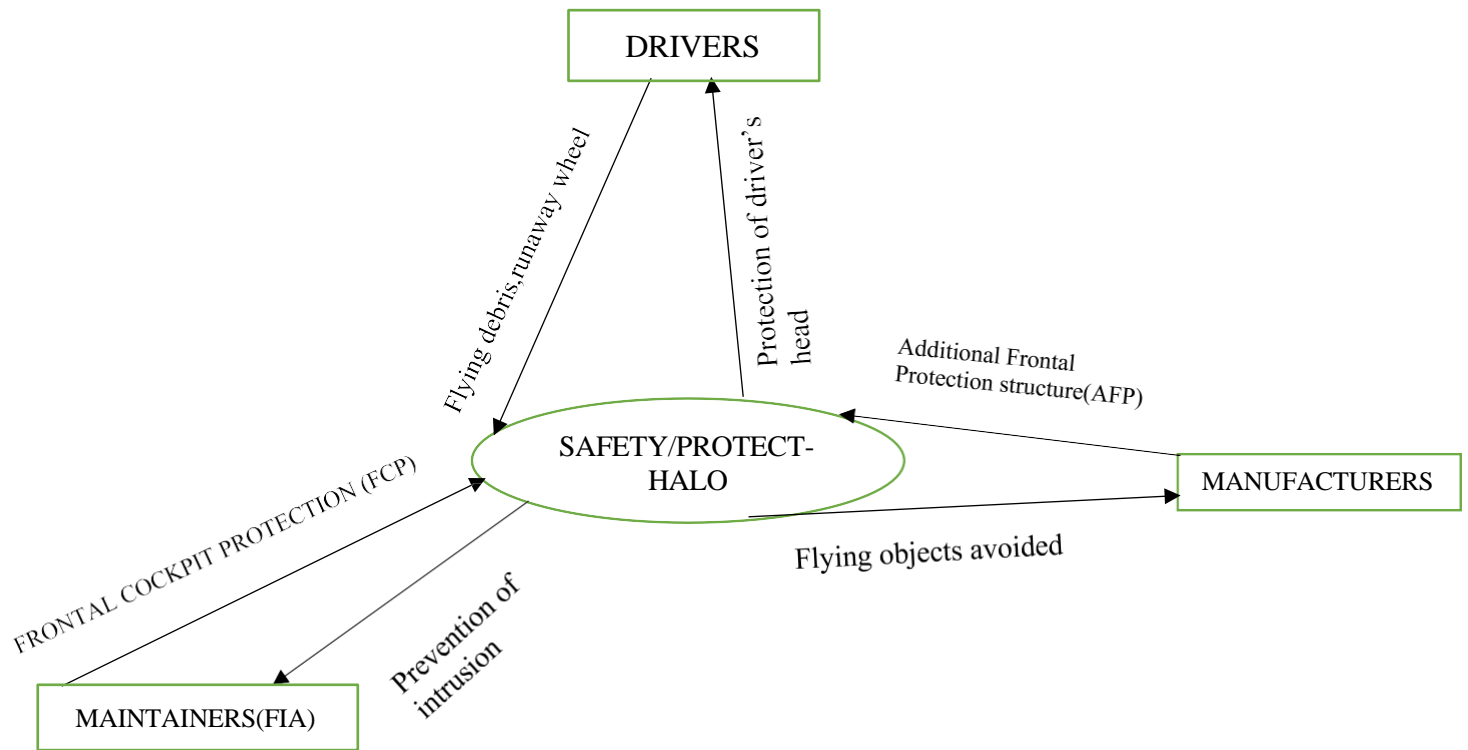
(c) Shield:

The Shield is a transparent open canopy system constructed using polycarbonate, and is aimed at providing significant protection from debris, while ensuring unrestricted forward vision for the driver. The shield is transparent and provides no obstruction of the driver's field of view and it can be retrofitted onto existing chassis.

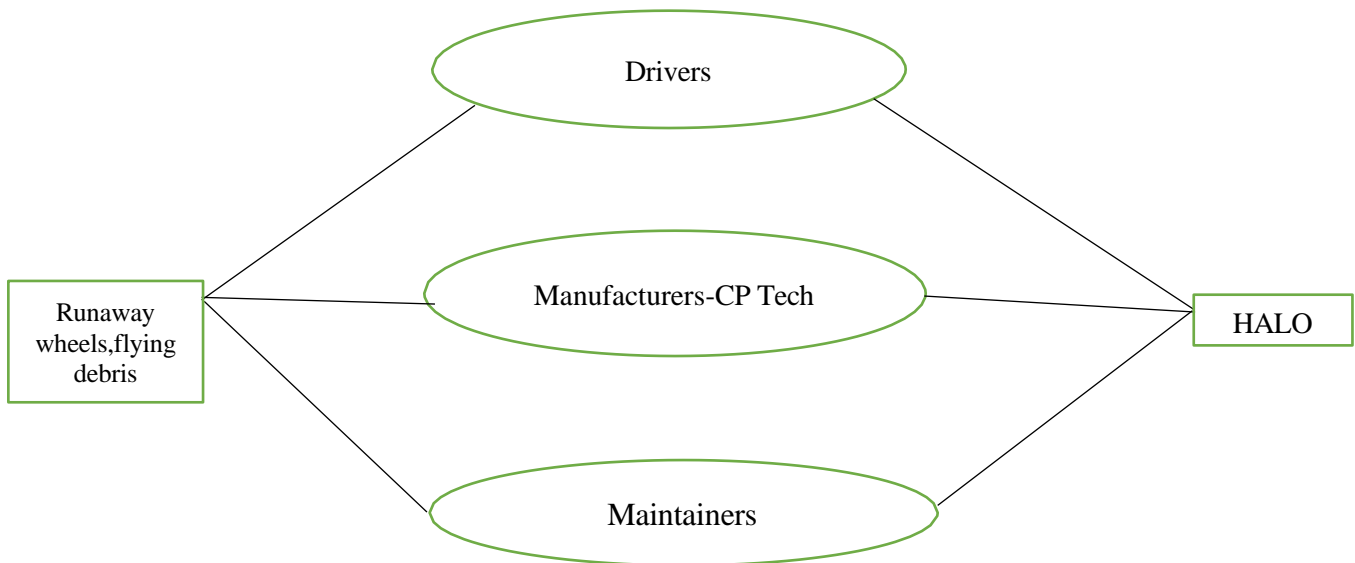
PUGH MATRIX

Pugh Matrix	System: Formula 1	Weight	Conceptual Design Solutions					
Shareholder Affected	Criteria		Closed Roof		Halo		Shield	
FIA	Maximise Safety of Driver in cockpit	0.3	+	10	+	9	+	8
Team	Minimise weight of the car	0.25	-	1	-	3	-	4
FIA	Minimise Budget	0.15	-	2	-	4	-	3
Driver	Minimise Injuries	0.3	+	10	+	9	+	8
Sum		1						
Number of +			2		2		2	
Number of -			2		2		2	
Number of s			0		0		0	
Net Value			0		0		0	
Weighted Score			6.55		6.75		6.25	
Best Alternative			HALO					

CONTEXT DIAGRAM:



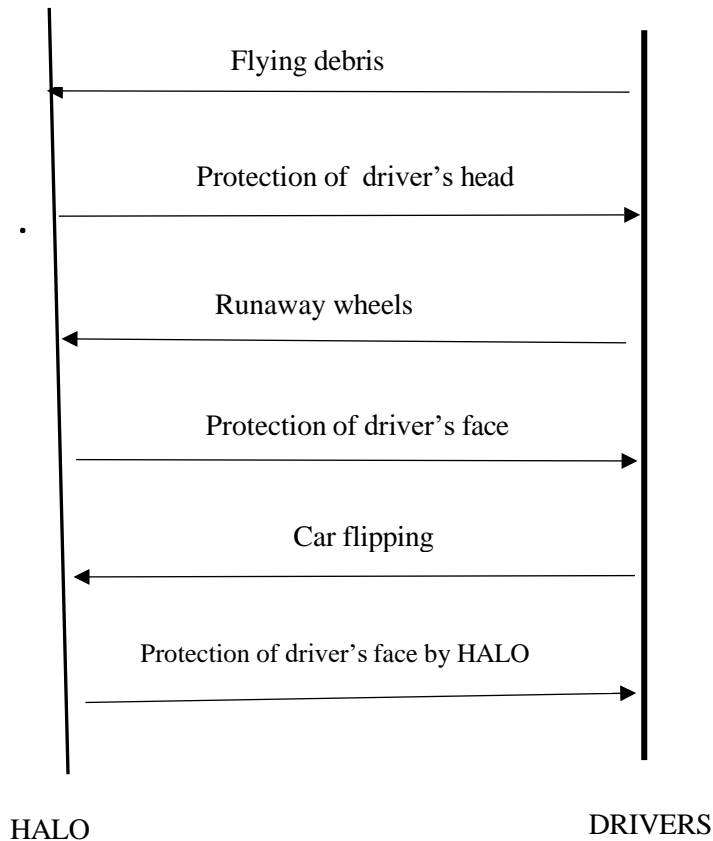
USECASE DIAGRAM:



SEQUENCE DIAGRAMS:

Sequence Diagram 1

Use Case 1: Drivers



Use case name: Drivers

Use case Purpose: Protect the driver's head from the flying debris and the runaway wheels(to keep the driver safe)

Actor: Drivers and HALO

Pre-condition: Drivers safety is given utmost importance. When the driver takes all the precautions during a race by being alert during a collision and avoid hitting himself to a flying debris or a runaway wheel.

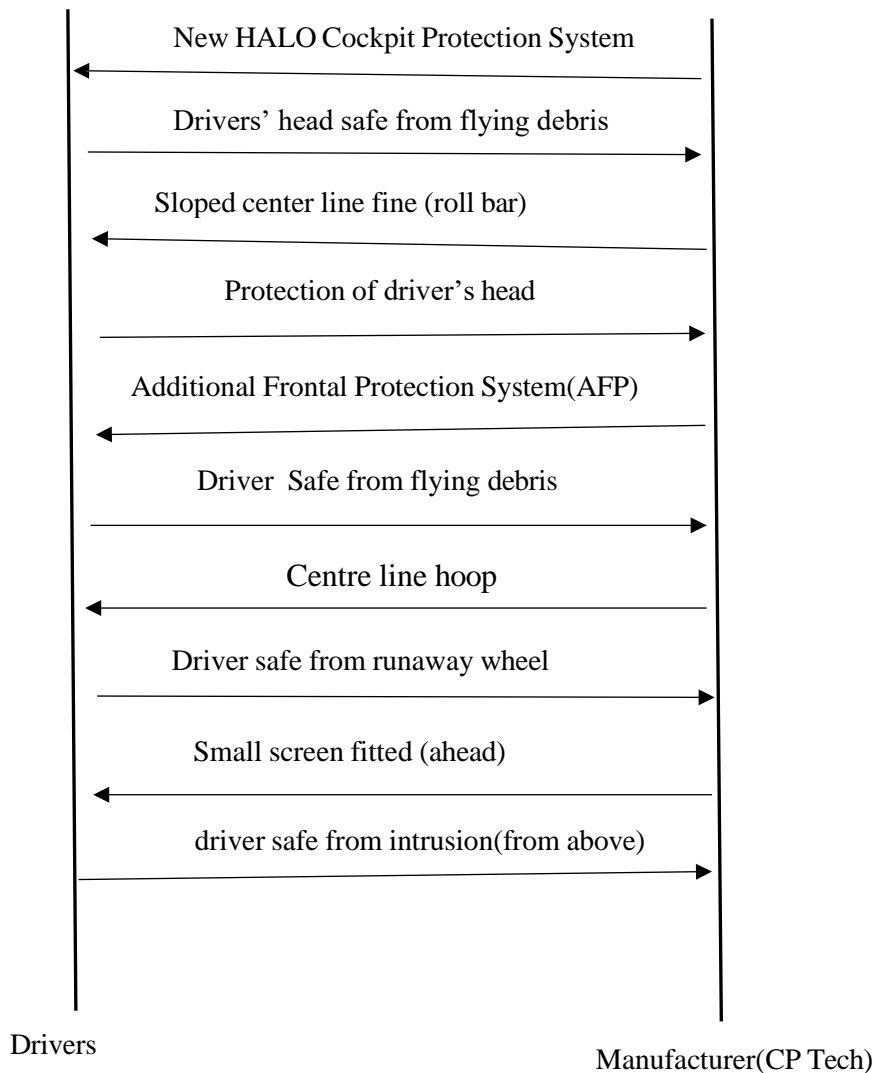
Post condition: The driver's head is safe from the flying wheel and avoids a runaway wheel, finally comes out safe after the race.

Basic Flow:

- Be safe from a flying debris with the help of a HALO
- Be safe from a runaway wheel with the help of a cockpit protection system.

Sequence Diagram 2

Use case 2: Manufacturer(CP tech)



Use case name: Manufacturer(CP-Tech)

Use case Purpose: To protect the driver's head from flying debris.

Actor: Manufacturers and drivers

Pre-condition: A Formula one race car should have all the safety components manufactured by CP-Tech. The race car should have a New HALO Cockpit Protection system which is manufactured by CP Tech. This system protects the driver's head from flying debris and runaway wheels.

Postcondition: A car which has all the necessary safety equipments lie the cockpit protection system will have the its drivers safe throughout the race.

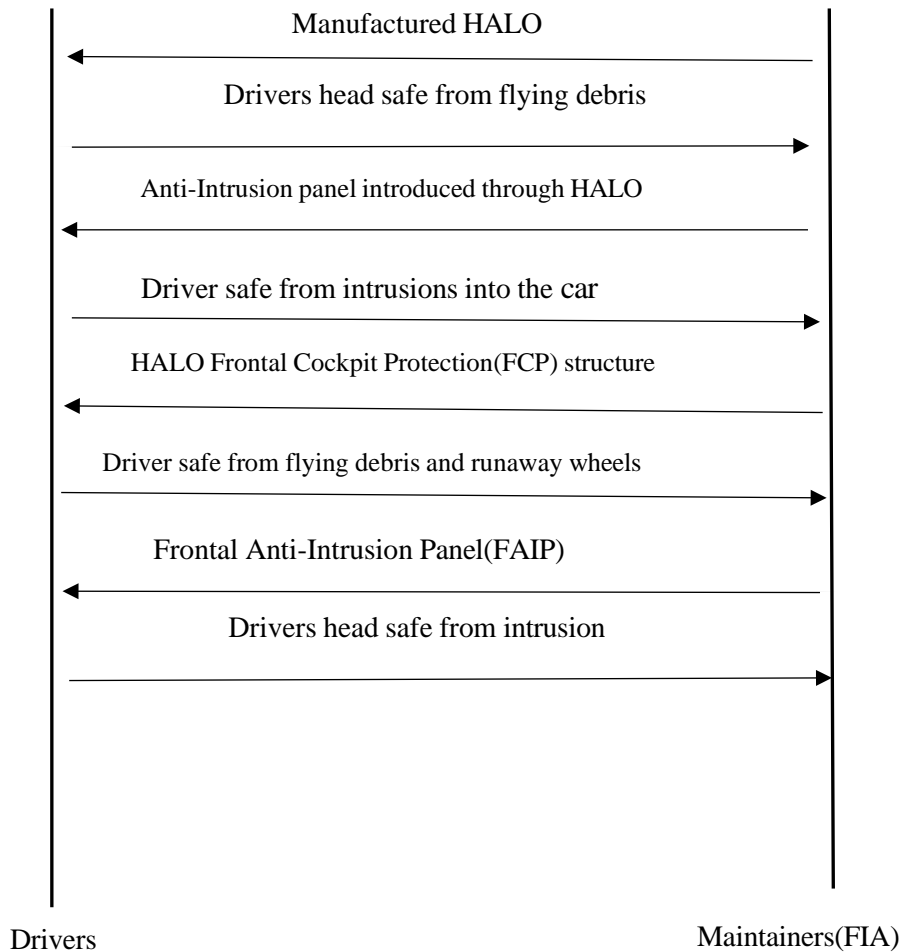
Basic Flows:

- New HALO Cockpit Protection System was introduced to protect the drive's face
- A sloped centre-lined fin was added for the safety of the driver's head
- An additional Frontal Protection (AFP) structure was added to deflect the flying or moving debris into the path of the driver.
- To deflect a runaway wheel from the driver, a Centre Line Roll Hoop was attached.

- The race car was fitted with a smaller screen ahead of the cockpit to protect the driver's head from any sort of intrusion into the car from above.

Sequence Diagram 3

Use case 3: Maintainers(FIA)



Use case name: Maintainer(FIA)

Use case Purpose: FIA designed the safety feature HALO. HALO was designed to prevent the intrusion of foreign objects to the car and to protect the driver's head from flying debris.

Actor: Maintainer and drivers

Pre-condition: Assuming the HALO which was designed by the maintainer FIA, is useful to drivers and is providing enough safety during the collision and keeping the driver's head safe.

Post condition: The race car which has a Frontal cockpit protection structure (FCP) and Front Anti-Intrusion Panel (FAIP) attached should keep the driver safe during the collision and flipping over of the car.

Basic Flows:

- Safety feature designed by FIA is the HALO
- HALO was designed to prevent the intrusion of foreign objects into the car.
- To prevent the intrusion, anti-intrusion side panels were introduced.
- The HALO Frontal cockpit Protection (FCP) was introduced to protect the driver from flying debris and runaway wheels.

- A Frontal Anti Intrusion Panel(FAIP) was attached ahead of the front to prevent penetration and intrusion into the car by any flying debris.

Concept of Operations:

1. Present Mode of Operations:

- Safety features have been updated with time in Formula One. For example, helmets (1952), fire-resistant suits (1975), the safety car (1993), Pit Lane speed limit (1994), barriers and run-off areas (1994), headrest (1996), The Head and Neck Support (HANS) device (2003), driver facing camera (2016) are few of the many things that were made mandatory by the FIA for improving safety and are still in use today.
- A focused push for increased cockpit protection started in 2009 when a driver lost his life and another suffered life-threatening head injuries in a matter of 2 weeks.
- The FIA, already several years into its research of additional head protection, put a provision for Halo in the 2017 technical regulations and started conducting on-track tests in early 2016.

2. Justification for Change:

- Increasing safety in the cockpit is something that is of utmost importance.
- At present, the cockpit of the driver is wide open and can cause serious damage if not life threatening damage to the driver, if hit by debris.
- The design concepts protect the drivers head from large pieces of flying debris as well as if cars launch on top of one another.
- Car accidents usually end up with cars piling or rolling over each other. The driver needs to be protected too.
- Sebastian Vettel was the first and only driver to try the Shield in a Formula 1 car. He completed a lap with the new system but ended the test early. He complained of distorted and blurred vision that prevented him from driving. Its introduction was subsequently excluded, as there was no guarantee that the issues with Shield could be solved in time for the 2018 season.

3. Future Mode of Operations:

- A study by the FIA using data from 40 real incidents revealed that a driver's chance of survival rose by 17% if a Halo was in use.
- Zhou Guanyu's accident at the 2022 British GP was a recent example of when Halo has saved a life. Most experts believe it would have been a fatal crash without Halo.
- The 2021 Italian Grand Prix saw drivers Lewis Hamilton and Max Verstappen collide, and Verstappen's Red Bull stopped with a rear wheel resting on the Halo of Hamilton's Mercedes, immediately above his helmet. After the incident, Hamilton stated that the Halo "saved my neck".
- When the Halo first arrived in 2018, there was criticism from drivers about its ugly looks and the potential for it to limit visibility. But that criticism has waned, and those who have been involved in accidents where the Halo has done its job sing its praises.

4. Operational Scenarios:

- If the FIA implements the Halo design in the chassis of the car then the safety of the driver in the cockpit is significantly increased but weight of the car increases too.
- If the FIA implements the shield design in the chassis of the car then the safety of the driver in the cockpit is increased but the visibility of the driver decreases.
- If the FIA implements the closed roof design in the car then the safety of the driver in the cockpit is increased but the visibility of the driver decreases.