Goals & Overall Vehicle Concept

What are goals?

Defining Goals

- Defining Goals
  - Long-term goals: e.g., competition success, development road map, team development
  - Short-term goals: e.g., podium finish in one season, improving lap times, increasing reliability
  - Finding the "right" goals:
    - Analyze strengths and weaknesses from past seasons
    - Benchmark against teams
    - Conduct internal team workshops to prioritize goals

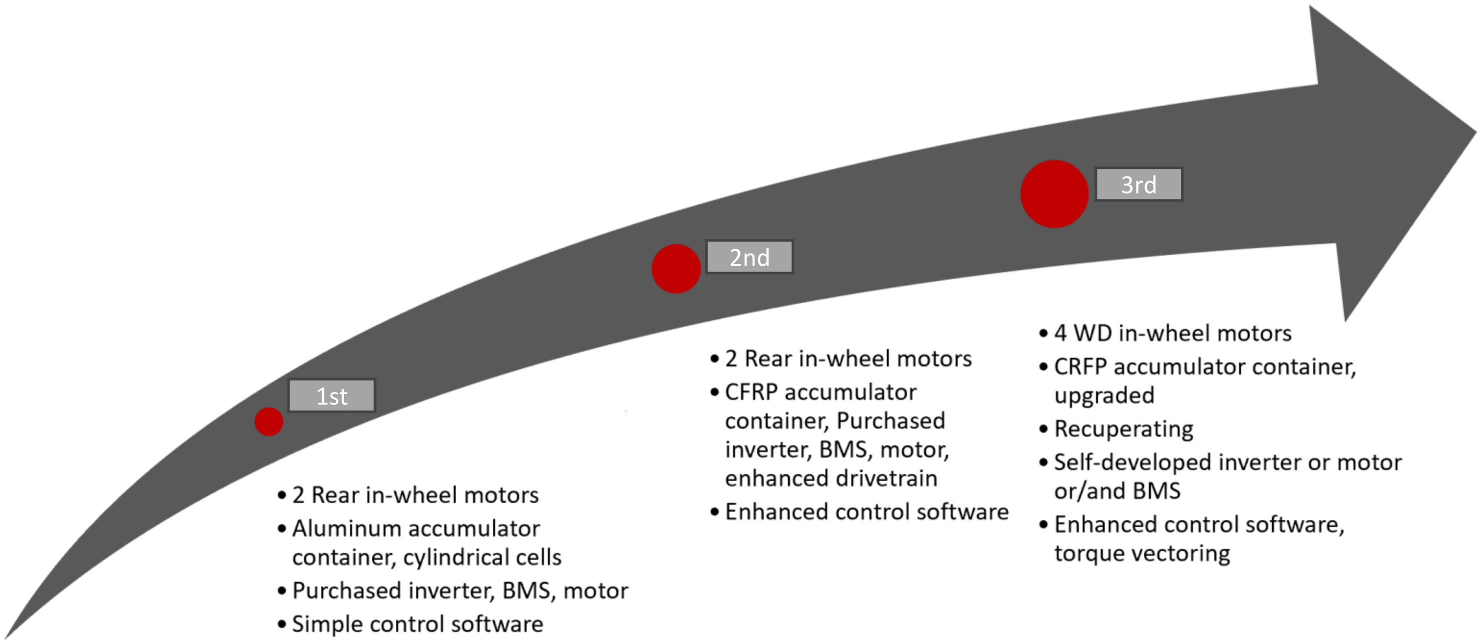
- Making Goals Measurable (SMART Approach):
  - Specific: Clearly defined goals (e.g., "Top 10 finish in Endurance")
  - Measurable: Quantifiable criteria (e.g., "Avg. Lap time under 75s on track")
  - Achievable: Goals should be realistic (e.g., based on resources)
  - Relevant: Goals should align with team and competition objectives
  - Time-bound: Goals must have a timeline (e.g., at FSA 2025 or FSAA 2025)

Long term goals definition

Long term goals

Short term goals

SMART Goal Definition



3 years development road map

FORMULA STUDENT AUSTRIA

Overall Vehicle Concept

- **Defining the Overall Vehicle Concept:** The design of the vehicle begins with the **“big picture”** – focusing on the main parameters and goals of the vehicle. These serve as the foundation for the entire design process. As critical decisions are made on large components and concepts, attention is gradually shifting toward smaller details, refining and optimizing the vehicle step by step.

- **Guiding Principles:**
  - The overall concept is grounded in the **team’s design philosophy** and **competitive goals**, which prioritize:

    Performance: Maximizing speed, reliability, and efficiency.

    Simplicity: Ensuring systems are robust and easy to maintain.

    Innovation: Using creative solutions that provide a competitive edge.

- **Design Philosophy: Complex but Simple**

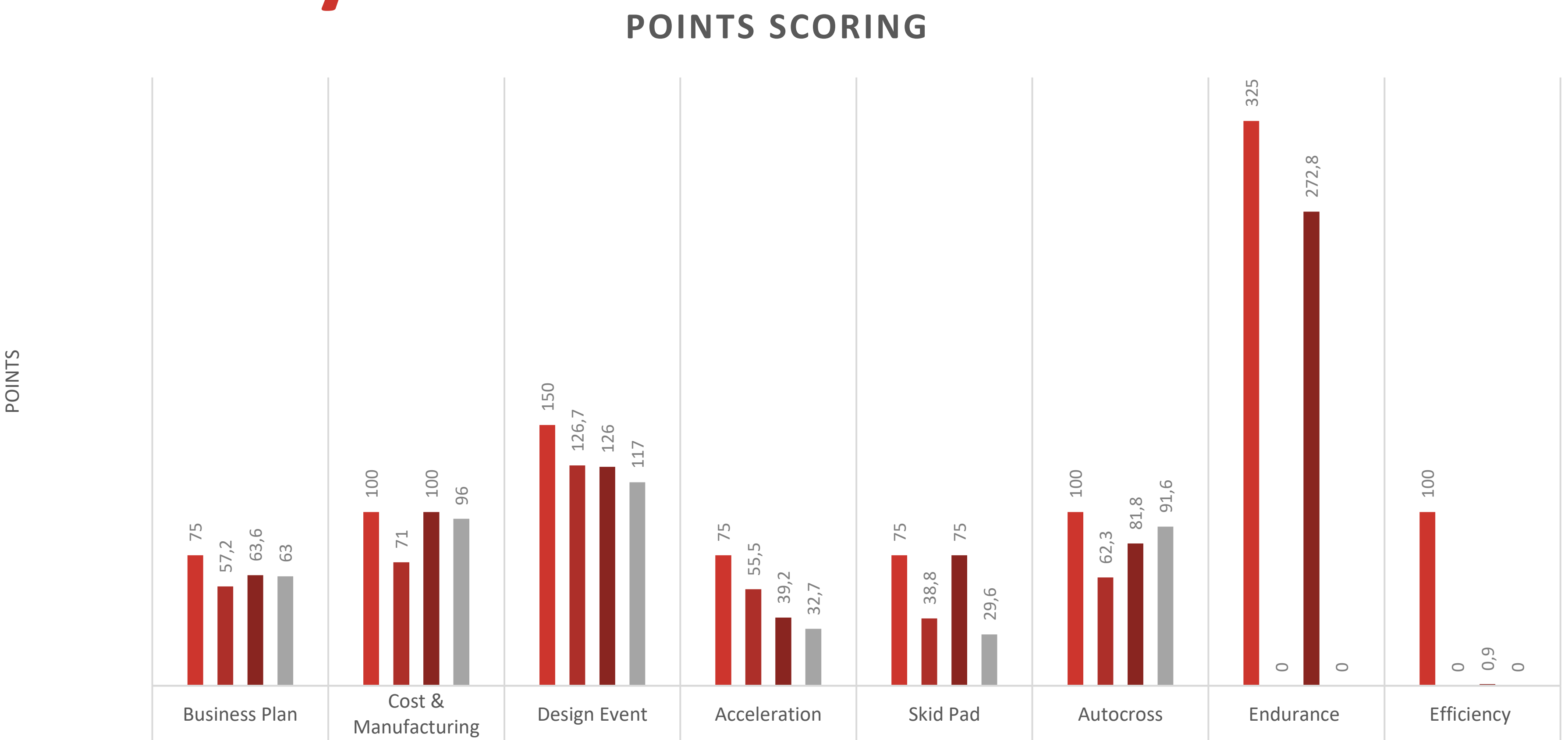
  - **Embrace Complexity Where It Matters:** Design advanced solutions for critical systems, like aerodynamics or powertrain, where performance gains are significant.

  - **Keep It Simple Everywhere Else:** Use straightforward, reliable designs for non-critical systems to reduce risk and streamline manufacturing and testing.

Deriving the Overall Vehicle Concept

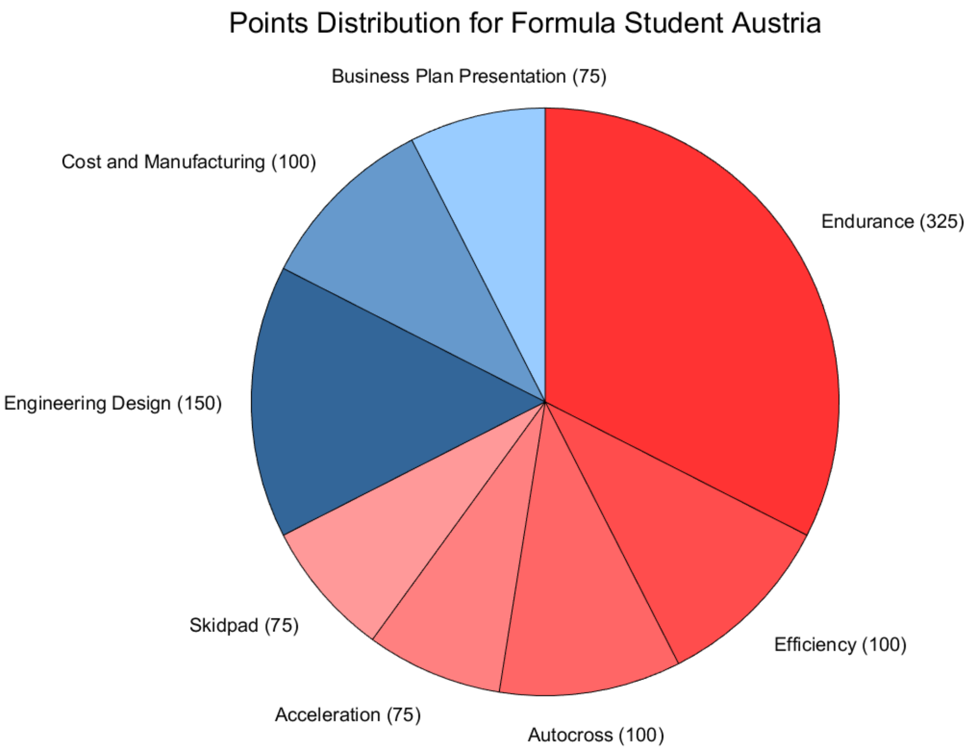
- Methods for Goal Quantification
  - Points analysis: Weighting the disciplines to overall competition
  - Lap time simulation: Identifying key performance factors
  - Sensitivity analysis: Understanding which parameters have the greatest impact on success

Points Analysis



	Business Plan	Cost & Manufacturing	Design Event	Acceleration	Skid Pad	Autocross	Endurance	Efficiency
Maximum	75	100	150	75	75	100	325	100
FSA	57,2	71	126,7	55,5	38,8	62,3	0	0
FS East	63,6	100	126	39,2	75	81,8	272,8	0,9
FS Alpe Adria	63	96	117	32,7	29,6	91,6	0	0

Optimizing Overall Competition Performance



$$M\_SKIDPAD\_SCORE = 0.95\, P_{\max} \left(\frac{\left(\frac{T_{\max}}{T_{\text{team}}}\right)^2 - 1}{0.5625} \right) + 0.05\, P_{\max}$$

$$M\_ACCELERATION\_SCORE = 0.95\, P_{\max} \left(\frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.5} \right) + 0.05\, P_{\max}$$

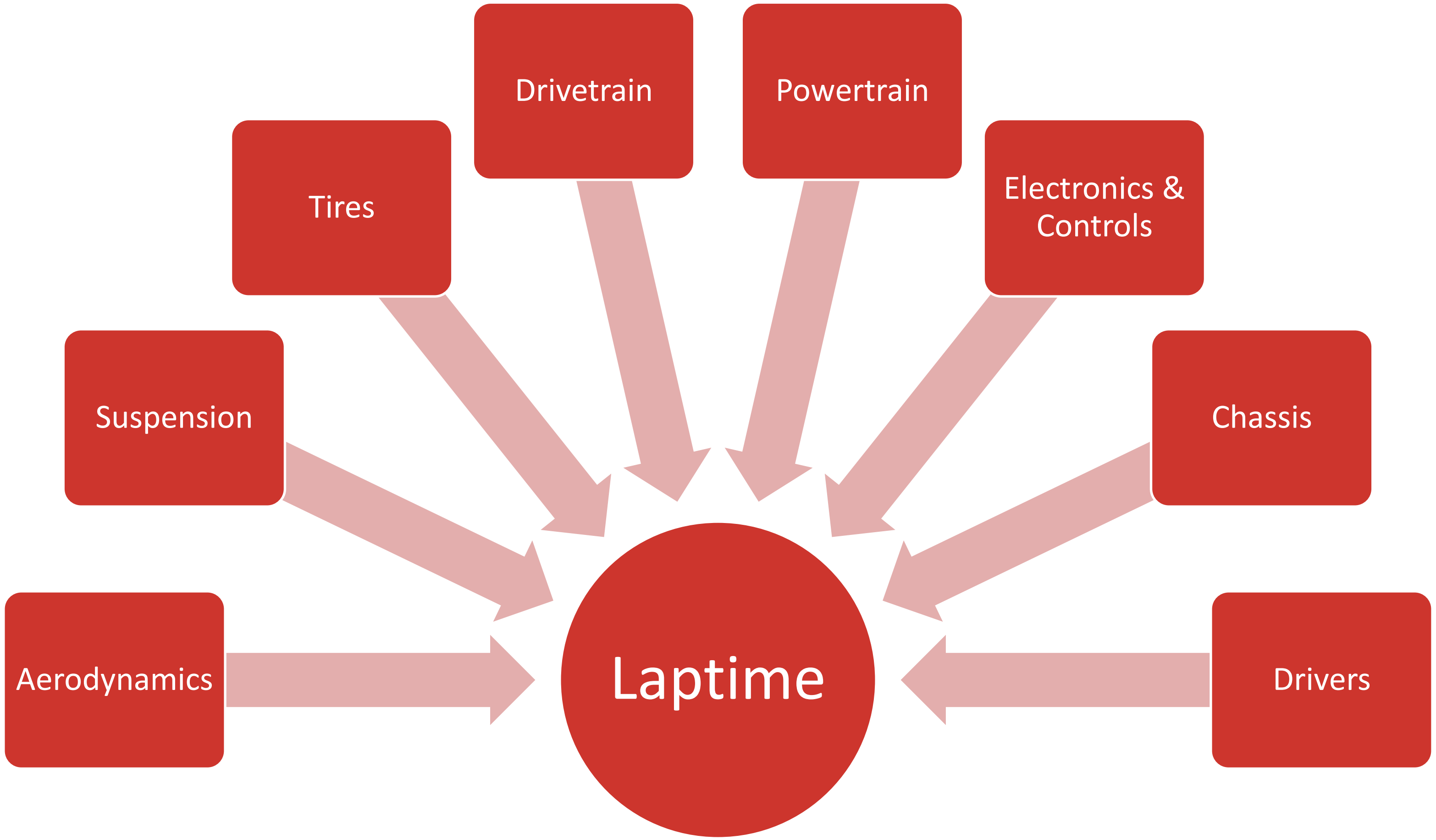
$$AUTOCROSS\_SCORE = 0.95\, P_{\max} \left(\frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.25} \right) + 0.05\, P_{\max}$$

$$ENDURANCE\_SCORE = 0.9\, P_{\max} \left(\frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.333} \right) + 0.1\, P_{\max}$$

$$EFFICIENCY\_SCORE = P_{\max} \left(\frac{EF_{max} - EF_{team}}{EF_{max} - EF_{min}} \right)$$

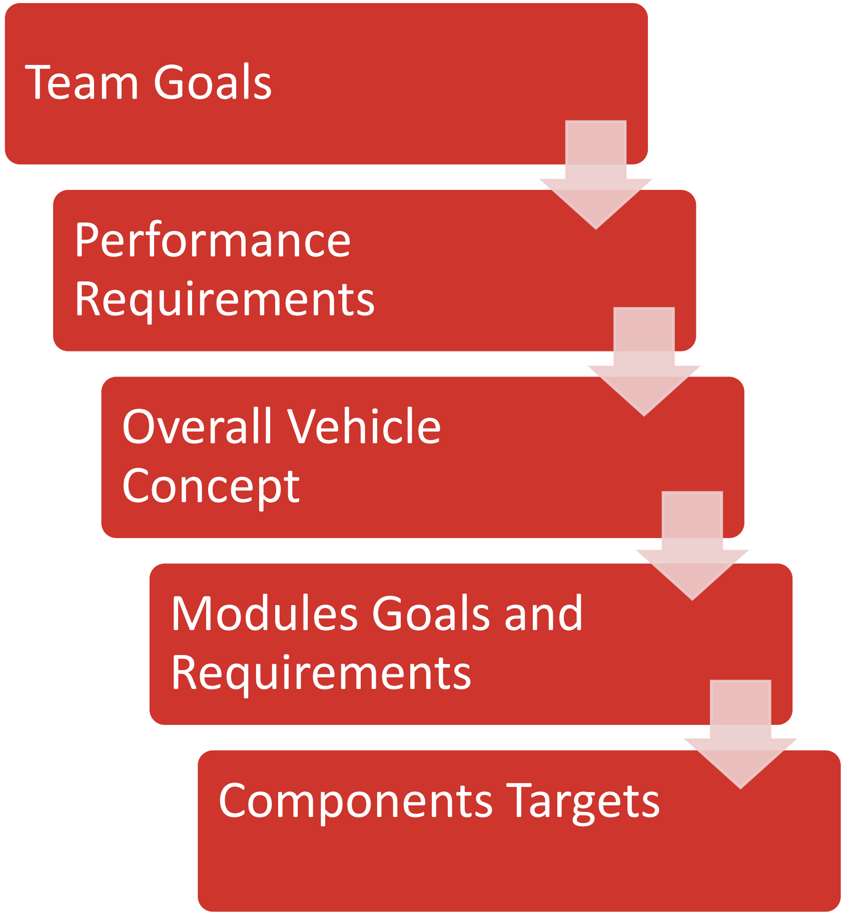
$$EF = T^2 \cdot E$$

Breaking Down Goals into Modules



Process Overview

1. **Define Team Goals:**
   Start by identifying the team's overall mission and objectives, such as performance priorities, innovation targets, or reliability benchmarks. This serves as the foundation for all design decisions.
2. **Translate Goals into Performance Requirements:**
   Convert the high-level goals into measurable performance metrics (e.g., weight targets, aerodynamic coefficients, energy efficiency) that guide the vehicle's design priorities.
3. **Develop the Overall Vehicle Concept:**
   Based on the performance requirements, define the main parameters of the vehicle, including powertrain architecture, aerodynamics, and weight distribution. This "big picture" drives subsequent decisions.
4. **Set Module Goals and Requirements:**
   Break down the overall concept into subsystem-level objectives (e.g., chassis, suspension, aerodynamics, powertrain) to ensure each module contributes effectively to the overarching goals.
5. **Define Component Targets:**
   Finalize specific targets for individual components within each module (e.g., motor efficiency, spring stiffness, wing profiles), ensuring alignment with the module and vehicle-level objectives.



FORMULA STUDENT AUSTRIA

What really matters for Performance ?

Spending 100 hours developing a new display interface with smartphone interaction?

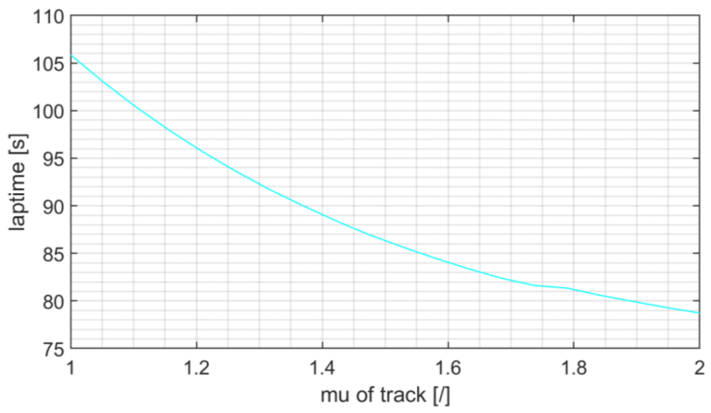
Spending 100 hours developing new suspension kinematics?

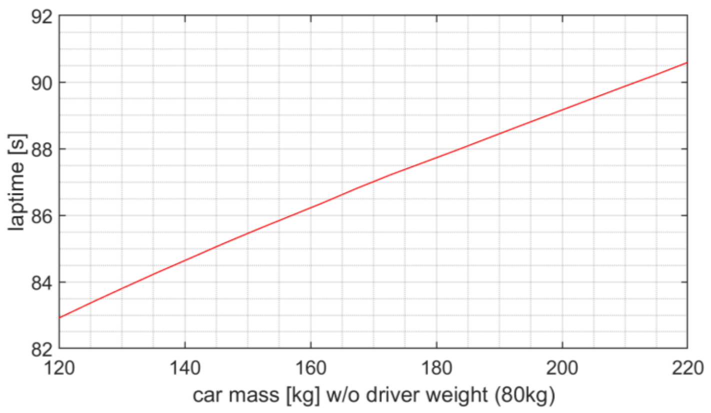
Source: https://www.formulastudent.de/pr/news/details/article/pats-corner-design-reports/

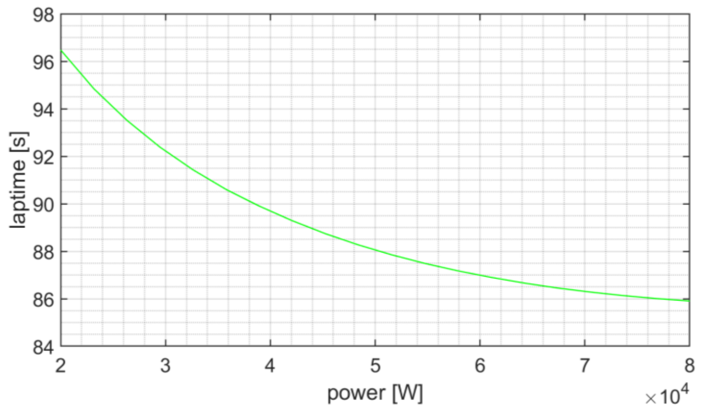
FORMULA STUDENT AUSTRIA

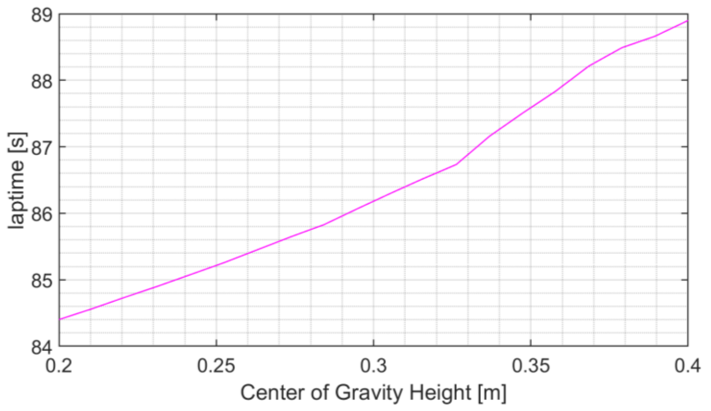
What really matters for Performance ?

1. Weight
2. Tyres / Grip
3. Power
4. Aerodynamics
5. Driver
6. Reliability

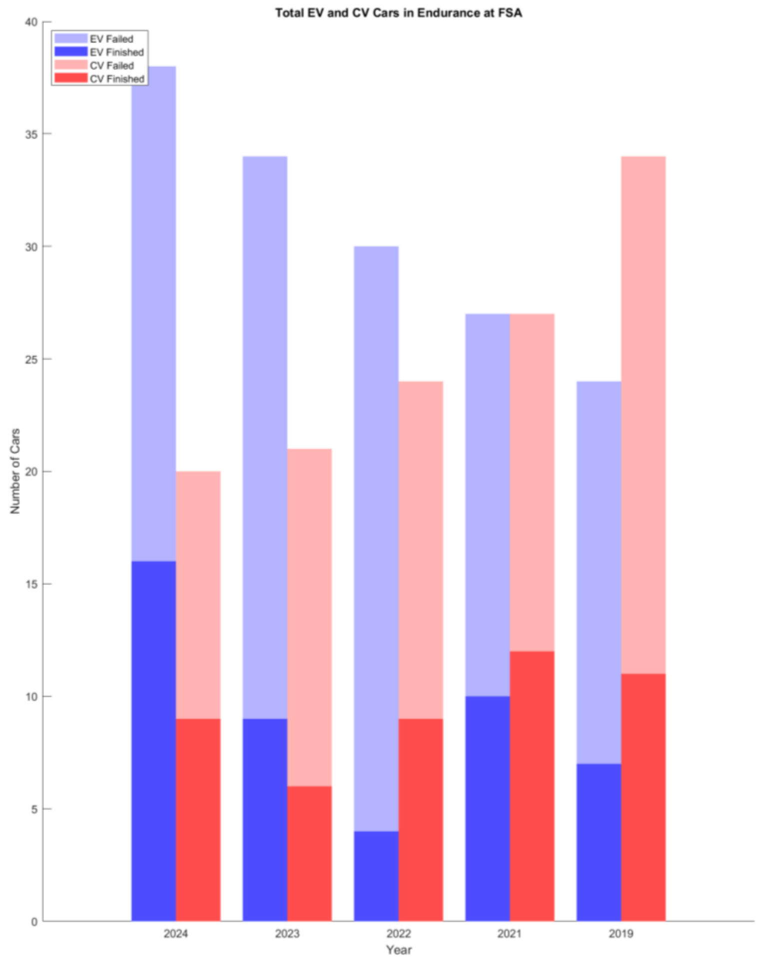


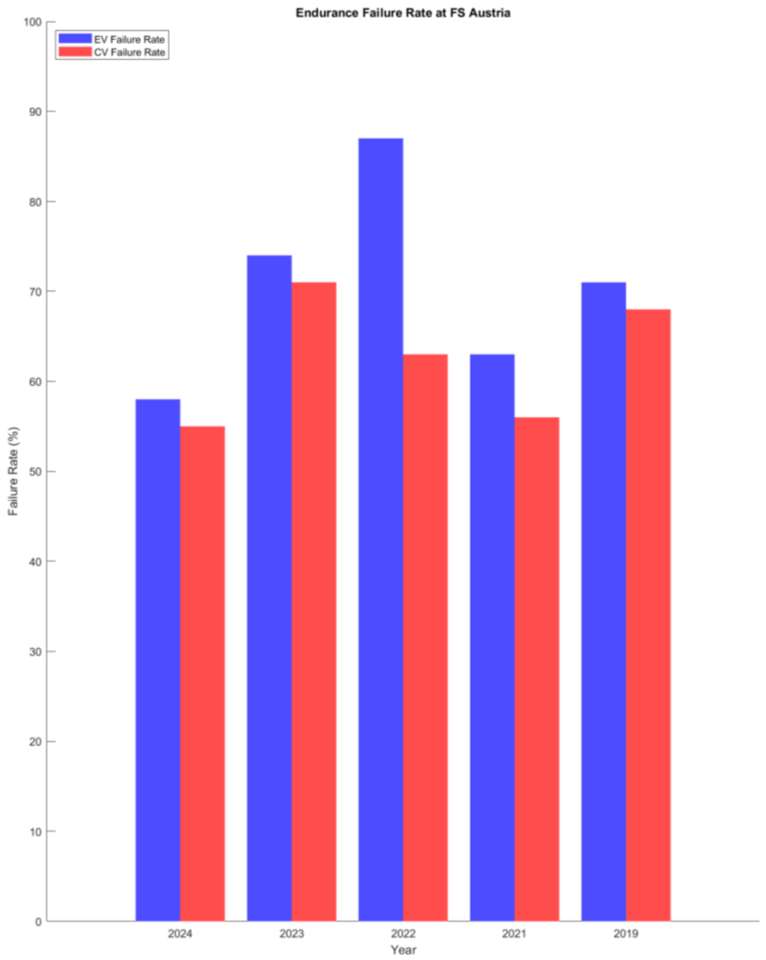






The Importance of Reliability





FORMULA STUDENT AUSTRIA

Risk Assessment & Prioritization

FORMULA STUDENT AUSTRIA

FS4A

ALPE ADRIA FORMULA STUDENT

Risk Assessment

1. Identify parameter
2. Evaluate parameter
3. Evaluate projects/decisions
4. Prioritize

Example – case study

- Overview last season
  - 3 competitions attended – no endurance finish
- <u>Goals</u> this season
  - Finish Top 10 in Skidpad at FSA2025
  - Best accelearation time at any competition below 4 seconds
  - Finish every endurance event without technical issues

Discipline	Best result 2024
Acceleration	P13 / 4.3s
Skidpad	P15 / 5.4s
AutoX	P11
Endurance	-
Efficiency	-

Car Parameter 2024	Value
Mass	215kg
cL	3.2
Powertrain	EV – 2WD
Vehicle control systems	Static torque distribution

Identify parameter

- What are my overall goals?
- What parameters are key for achieving my goals?
  - **Performance** - what is the raw performance of the car
  - **Reliability** - how reliable does it run?
  - **Feasability** - level of manufacturing & assembly complexity -> affects timeplan significantly
  - **Resources** - how many resources (time/money/people) does it demand?

Evaluate parameter (based on goals)

- Scale: 1 (low relevance) – 5 (highly relevant)
- Score always depends on the necessary progress of each team to achieve their goals

	Performance	Reliability	Feasability	Resources
Top 10 Skidpad FSA25	4	2	1	2
Acceleration < 4s	4	3	1	3
Finish every endurance	1	5	4	3
Average score	3	3.3	2	2.7

Evaluate projects / decisions

- Scale: 1 (negative impact) – 5 (positive impact)

Raw Scores

	Performance	Reliability	Feasability	Resources	Avg. score
Keep steel tube chassis concept	2	5	5	3	3.75
Build „simple“ carbon fibre Monocoque	3	3	2	1	2.25
Build slim and very light weight carbon fibre Monocoque	4	2	1	1	2

Prioritize

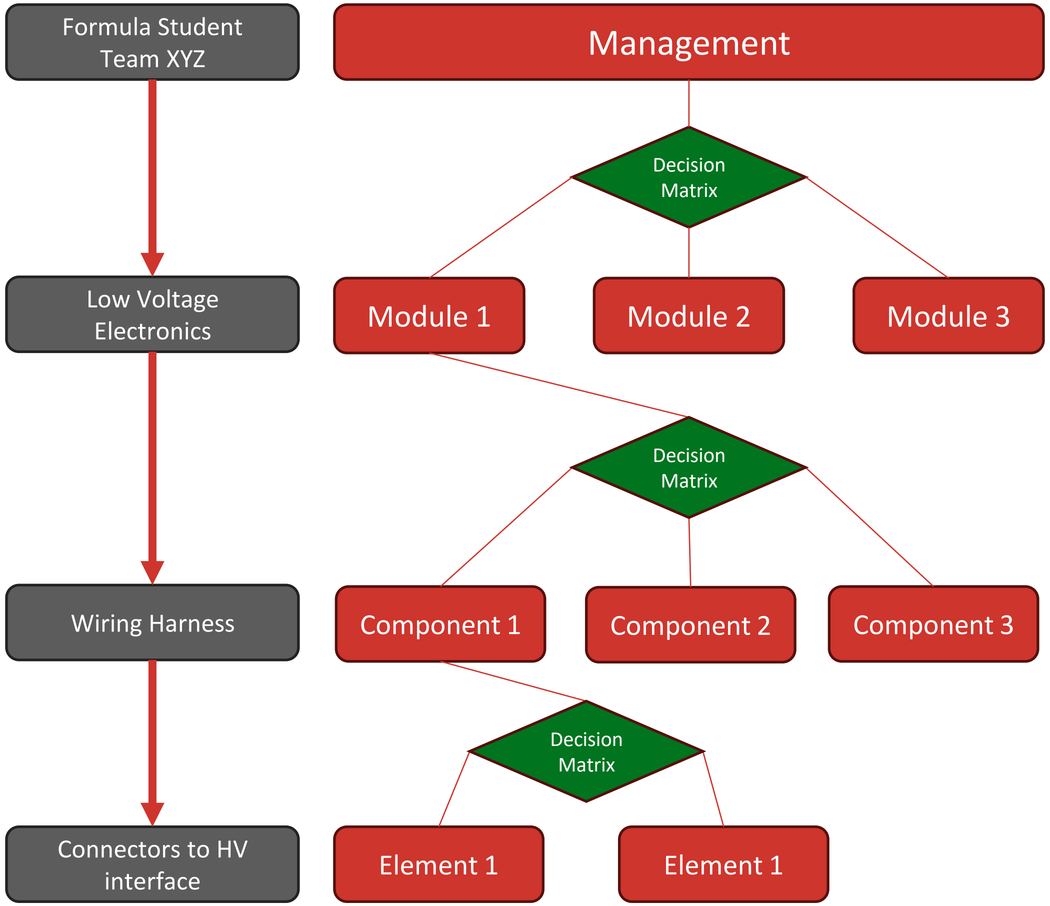
- Multiply parameter score with each project score per parameter = Weighted score

Weighted Scores

	Performance = 3	Reliability = 3.3	Feasability = 2	Resources = 2.7	Total score
Keep steel tube chassis concept	2x3 = 6	5x3.3 = 16.5	5x2 = 10	3x2.7 = 8.1	**40.6**
Build „simple“ carbon fibre Monocoque	3x3 = 9	3x3.3 = 9.9	2x2 = 4	1x2.7 = 2.7	25.6
Build slim and very light weight carbon fibre Monocoque	4x3 = 12	2x3.3 = 6.6	1x2 = 2	1x2.7 = 2.7	23.3

What to do with that fancy number?

- This method is applicable to all levels -> Top down
- The higher the hierarchy level of the analysis the more depth of the parameter analysis is needed!
- FMEA Analysis is derived from this method -> purely focused on risk assessment



Reliability

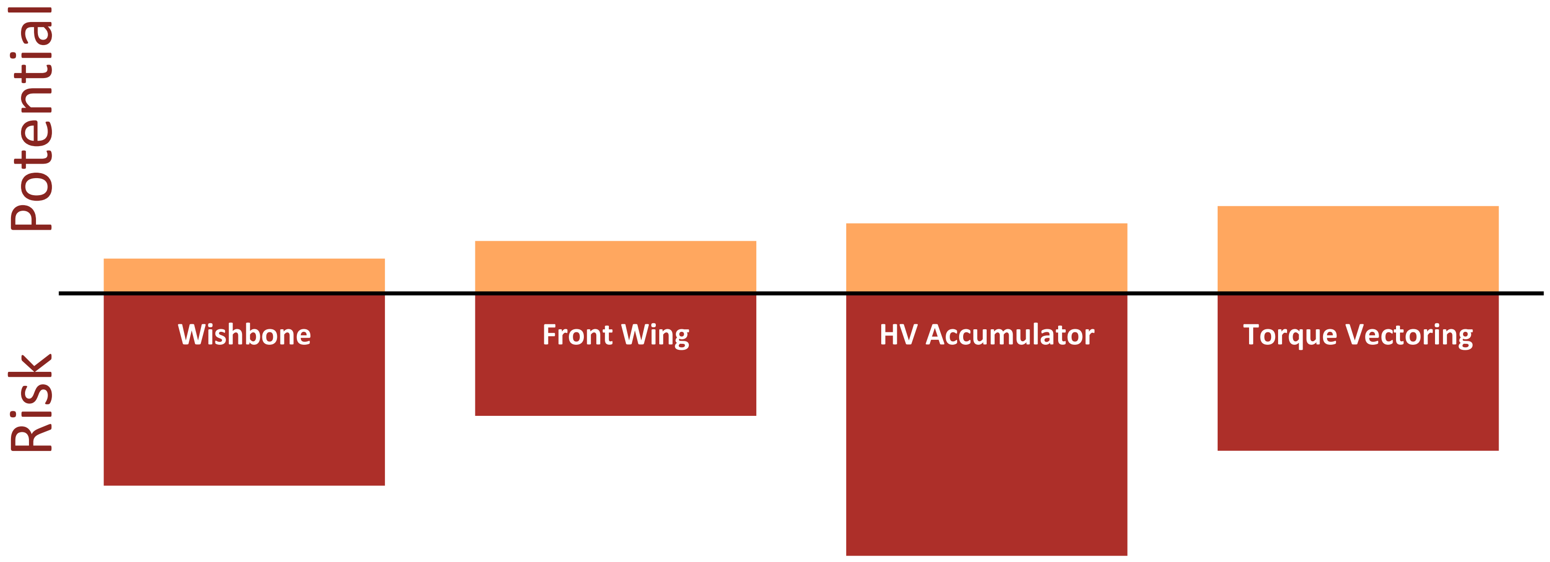
FORMULA STUDENT AUSTRIA

FS4A

FORMULA STUDENT

Why is Reliability important?

- Obviously!
- *„The loss in case of system failure is far greater than the gain if everything works out"*



Reliability - Process

1 Analyse

1. SMART Reliability goals
2. Sub-goals per module
3. FMEA-Analysis

2 Monitor

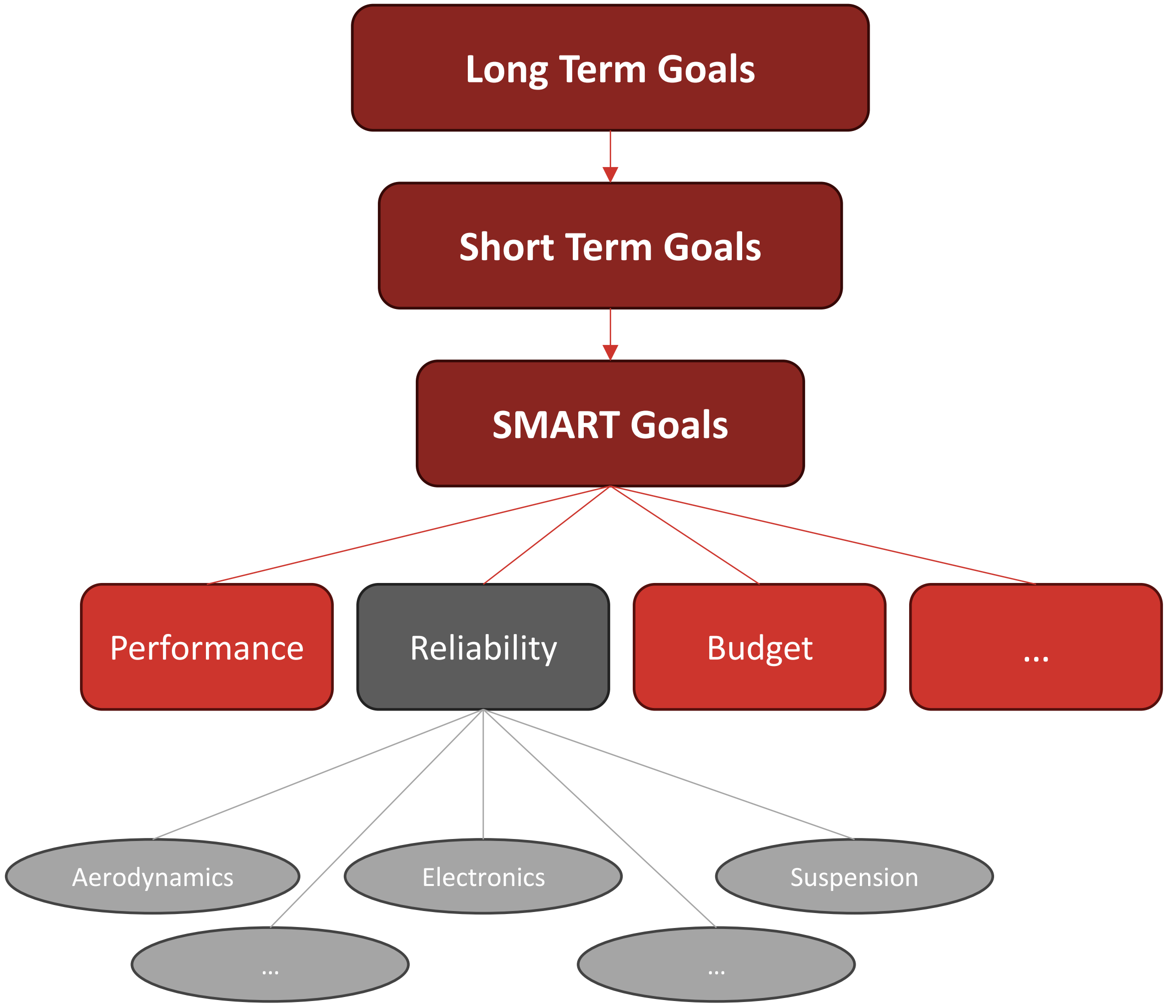
Create easy and quick monitoring processes

3 Validate

Compare results of each project phase with initial goals

Goals

1. Define reliability goals -> SMART approach!
2. Break down overall goals to each module
3. FMEA-Analysis
   - Identify failure modes
   - Evaluate risks of failure
   - Find measures to encounter potential failure modes
   - Validate and monitor the process



FMEA Analysis

1. Goal -> Finish Endurance in FSA & FSAA 2025 without major technical issues
2. Module goal (e.g.Suspension)-> No suspension failure, no leakage of fluids, constant ride height, …
3. FMEA Analysis -> Evaluate components responsible for achieving goal

Component	Potential Failure Mode	Potential Effects of Failure	Potential Causes of Failure	Severity 1 - minimal 10 - catastrophic	Occurence 1 - unlikely 10 - frequent	Detection 1 - likely 10 - impossible	RPN (=Risk Priority Number)	Action
Wishbone	Mechanical failure	DNF	Forces too high for mechanical structure	10	3	8	10x3x8 **= 240**	Adapt mech. structure based on FEM-simulation and component tests and validation on test bench
Dampers	Slight Leakage of damper fluid	Decrease in mechanical grip	Poor maintenance, sealing failure	2	6	4	2x6x4 **= 48**	Regular maintenance intervalls for dampers and additional leakage checks before each discipline
Ride-Height Adjuster	Incosistent ride heights	DSQ in post-scrutineering	Plastic deformation within mechanism	7	6	3	7x6x3 **= 126**	Redesign mechanism and manufacture fallback part with fixed length at safe ride height

FORMULA STUDENT AUSTRIA

RPN interpretation

0 – 100
Low risk: no immediate action needed

101 – 200
Medium risk: actions recommended, especially if easily feasable

201 – 500
High risk: actions are necessary and need high prioritization

501 – 1000
Very high risk: immeadiate shift of resources to take action ASAP

Component	Failure Mode	RPN
Wishbone	Mech. failure	**240**
Damper	Slight leakage	**48**
RH - Adjuster	Inconsistent RH	**126**
…	…	**…**
…	…	**…**

Practical tips FMEA

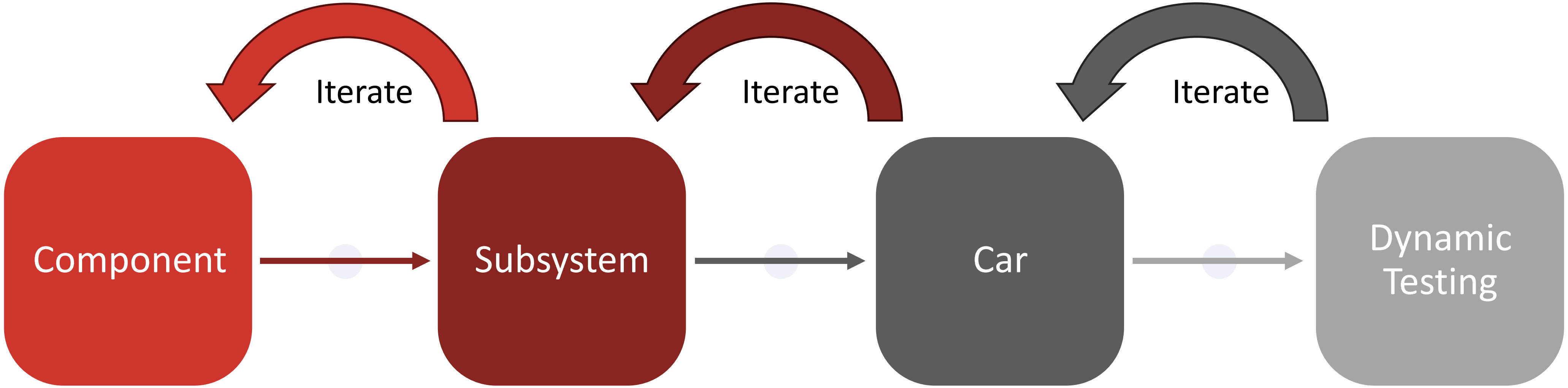
- Evaluation is always subjective!
- Find a scale as objective as possible
  - What does „Severity=8“ equal to?
  - What Likelihood of detection is „Detection = 5“?
  - …
- Trends, not absolute Numbers!
- FMEA results only compareable betweeen modules if…
  - Same project phase
  - Same scale of evaluation
  - Same level of detail

Monitoring

- Each action deriving from FMEA analysis and its progress must be monitored
- **Quick** and **clear indication of status** during all phases of development must be given
- Implement your debugging modes early!

Component	Failure Mode	Action	Monitoring
Wishbone	Mechanical failure	Adapt mechanical structure based on FEM-simulation and component tests and validation on test bench	**FEM simulation and test bench results**
Shut-Down-Circuit	Physically damaged wire, false positive shut down	Advanced protection at critical positions + optimized wiring path	**Indication lights and easy to access measurement points for quick debugging**
VCU-Software	Implausible input signals to inverter	Use VCU in the loop setup for function development	**Quick debugging via clear and distinct error meassages for each model-subsystem and its edge cases**

Validate



Component

- Basic functional tests
- Test bench or „XY in the loop“ tests

Subsystem

- First integration tests
- Validation of interfaces

Car

- Basic validation of whole system
- Packaging, communication and basic function validation

Dynamic Testing

- Full system test and validation
- Target is endurance simulations at test track

Testing

Testing Methodology and Structure

Importance of Testing:

Testing the vehicle is critical to identifying and resolving issues, increasing the reliability and performance of the car. A structured testing process ensures systematic improvement at every stage of development, culminating in a competition-ready vehicle.

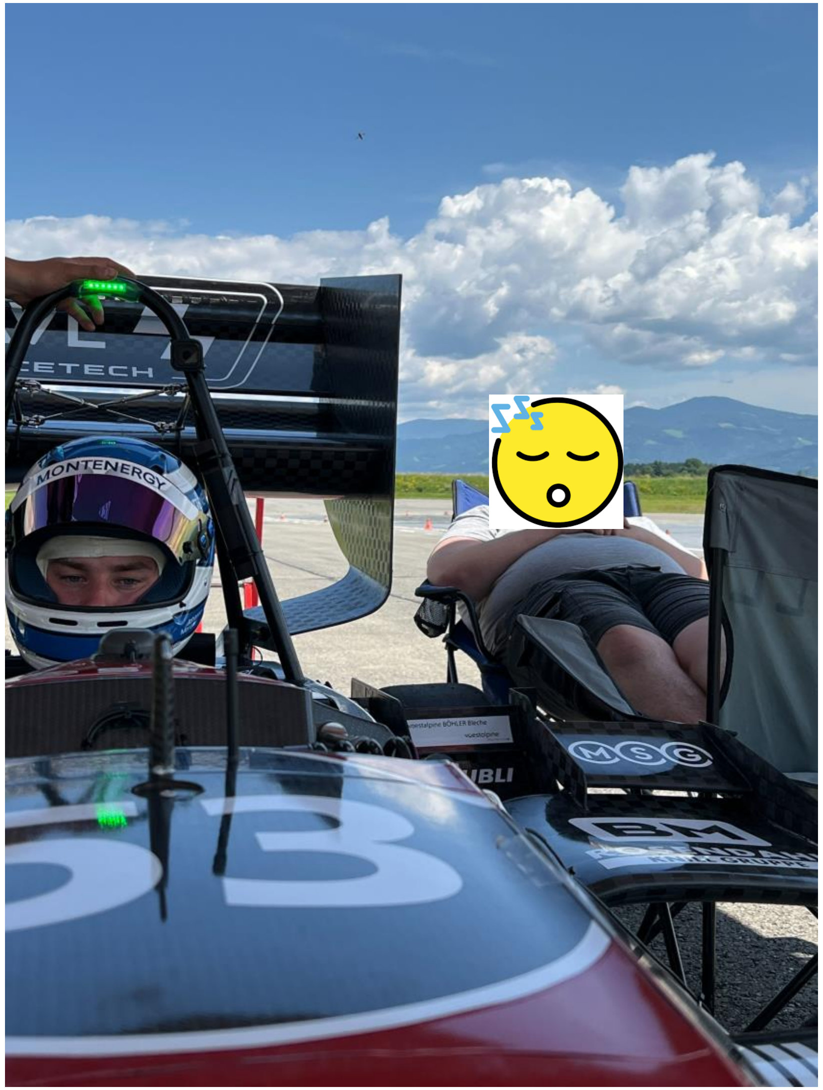
Phases of Testing:

- **Shakedown Testing:**
  - Objective: Verify basic functionality of systems (e.g., electronics, powertrain, suspension).
  - Focus: Ensure the car operates safely and systems work as expected.
  - Example Tests: Power-on tests, basic braking, and initial low-speed runs.
- **Full System Integration:**
  - Objective: Evaluate how all subsystems work together in real-world scenarios.
  - Focus: Ensure the car meets reliability and endurance goals under combined loads.
  - Example Tests: Endurance simulations, heat management, and integrated system tests.
- **Competition-Ready Testing:**
  - Objective: Test the vehicle in its full competition specification.
  - Focus: Validate all systems and finalize setup for competition conditions.
  - Example Tests: Full simulation of competition events (acceleration, skidpad, endurance).

FORMULA STUDENT AUSTRIA FS4A ALPE ADRIA FORMULA STUDENT

Testing Efficiency

- **Key Objectives for Testing:**
  - Ensure the car is **scrutineering-ready** as early as possible; missing components should be integrated quickly to allow comprehensive testing.
  - Create a **detailed testing plan with clear targets** before the testing period, including endurance runs as a priority to validate reliability and prepare for competition conditions.
  - Allocate sufficient **seat time for all drivers** to ensure they are ready for their respective disciplines.
- **Preparation and Flexibility:**
  - Arrive at the test day with a **specific plan** and backup options to adapt to unforeseen issues.
  - Complete as much preparation as possible beforehand (e.g., VCU software flashing, setups, maintenance).
- **Testing Efficiency:**
  - Include time in the plan for **maintenance** and **data analysis** to address issues and refine the car setup during testing.



Testing Documentation

Testing Documentation

- Weather Data (Track and Ambient)
- Telemetry
- Setup Sheet
- Video Onboard
- Testday log with Laptimes

Driver Debrief

- Feedback on car handling
- Usability and comfort of controls
- Ergonomics
- Driver Training

Team Debrief

- Subsystem-Specific Feedback
- Component Health
- Performance and Reliability Insights
- Maintenance

Components runtime sheet

- **Track Kilometers per Component:**
  Record cumulative mileage for critical parts (e.g., suspension, drivetrain, electronics).
- **Issue Log:**
  Document issues with components or systems that didn’t perform as expected.
  Highlight areas for improvement and prioritize fixes.
- **Plan Maintenance Intervals:**
  Schedule replacements before failure based on runtime data.
  Ensure reliability during critical events.
- **Analyze Lifespan and Reliability:**
  Identify weak points and recurring failures post-season.
  Adjust design, materials, or maintenance intervals as needed.
- **Optimize Future Performance:**
  Use data to refine reliability goals and improve component durability.

FORMULA STUDENT AUSTRIA

Q&A Session

If you have further questions,
please write us at Rules@fsaustria.at

Q&A for Session 4

Question	Answer
Why is not a 110% lap time or similar used in endurance everywhere? Everyone wants to finish endurance but if someone's car drives 30 km/h and can be overtaken only in the allocated places this will ruin other teams' competition.	There are Rules in place for this, it is just that the threshold is a bit more lenient because we want to give every team the opportunity to finish the endurance and get the points. If your car was the slow one, you would also like this to be the case. We put a lot of effort into properly managing the overtaking zones so that faster cars are not held up behind slower ones. Also, we limit the number of cars which run at the same time to four which also reduces the issue.
How do you judge the effect on laptime of possible changes to your car that you cannot predict with laptime simulations? If testing with the old car is also not possible.	If you do not have data, you can try to extrapolate and make reasonable assumptions from the data you have or you can try to get data from other teams, the FS community is normally quite open for that!