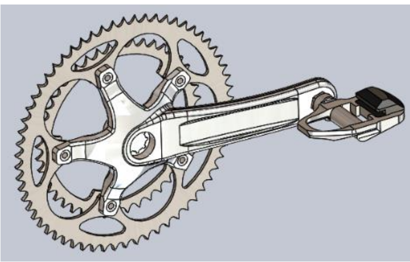
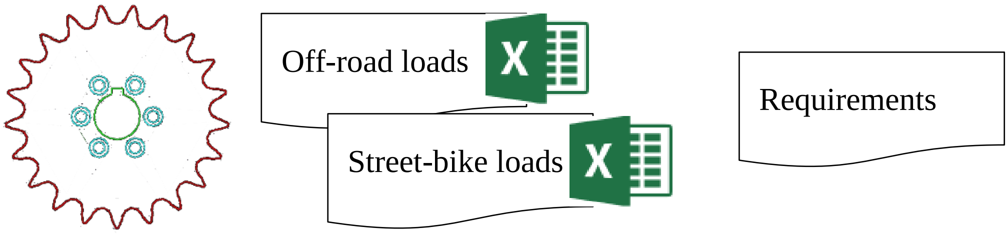


Scenario Overview: For weight and cost reasons, The bicycle company's management wants to use the same pedal crank set assembly on all of their models (off-road and long distance street bike versions). Based on a set of requirements for each model, the bicycle company's Engineering department has asked the chain ring Supplier to provide analysis models and associated documentation that defines the best version to use.

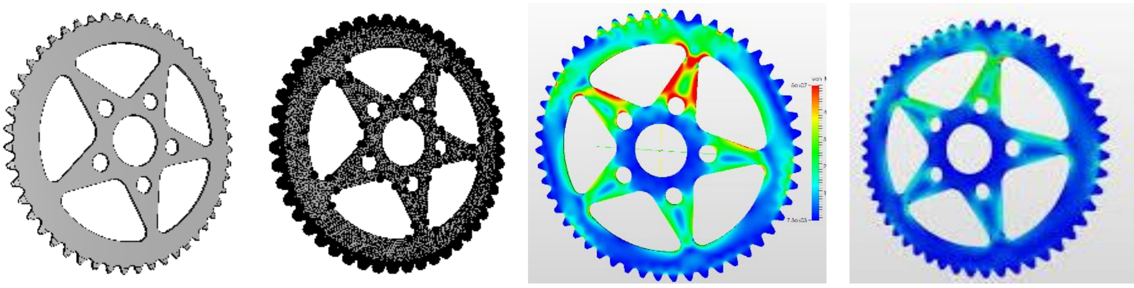
OEM provides the Specifications:

- A CAD 3D interface model (bike and pedal assembly)
- Two Loads models (at bolts and teeth), as excel spreadsheet, one for each variant (off-road and street)
- Design Requirements: max weight 50g, max cost $20, loads factor of safety (FOS) margin = 10%



Supplier provides Design Solutions/Alternatives:

- A CAD model, a linear "black box" Finite Element (FE) model and two sets of analysis results for the two variants



- A note that the FE model was validated up to +10% FOS using the supplied loads with ±3% uncertainty. Increasing to 10-20% range gives 10% uncertainty, and >20% should not be used.
- KPI for component weight (55g) and cost ($15)
- loads margin Key Performance Indicators (KPI) for each variant
  - street = +30% FOS with uncertainty ±2%,
  - off-road = +12% FOS with uncertainty ±2% assuming "non-extreme" use
- Proposal to change material and reduce weight (to 30g) with cost penalty ($25), but off road margin increase to 15%.
- Proposal to increase the number of bolts from 5 to 6 to reduce weight (45g) at reduced cost ($15) with off road margin increase to 15%

Workshop Exercise: To support traceability and future reuse, what additional pieces of information (Who, What, When, Where, Why, How) should be recorded and associated with the supplier's models? **Write down** the ten most important features to capture as part of this data exchange.

Information Examples:

1. The material specification and surface finish used for the analysis
2. CAD tolerances (e.g. thickness) used for the analysis

From the Workshop Audience:

Traceability items: higher level analysis that drove to change bolt pattern; requirements decomposition
Proposal justification
Traceability items – element mesh, pedigree, other analysis
Rights to reuse the model that was received
Warranty, risks, materials changing
Cost – where come from? Can we get cost data?
What's the justification for the proposed cost changes? If we knew, we might be able to get them more cheaply
Production quantity, rate of production
Rider weight (missing req't)
Load case file should be derived form rider weight
Supplier model traceability to OEM
Mfg location/process/value stream map
Alternate materials and supporting analysis used for trade study
Interface req'ts – need to know if willing to do that (traceability)
Link geometry models to variants
Link analysis results to appropriate variants
OEM want to integrate at higher level (with system model)

From the MoSSEC Team:

Information to record:

- **Model inputs -** Link the supplier CAD and FE models to
    - OEM CAD model of bolt and teeth patterns
    - OEM Loads models
- **Model outputs**
    - Link the supplier models as created by and owned by the supplier, on date.
    - Link the supplier results models as derived from the supplier FE model
    - Link the weight and cost KPI to the supplier CAD model
    - For each variant link the margin KPI to the supplier results models, and link the uncertainty to the margin KPI
    - Add link from supplier method to the FE model
- **Assumptions and Justifications**
    - Add the "non-extreme" assumption to the FE results for the off-road
    - Add an approval (to be signed off by the OEM chief architect) that the assumption is acceptable
    - Add a justification to the approval that the warranty excludes "extreme".
- **Supplier Method**
    - Type = "Linear FE"
    - Resource = FE model
    - Inputs = loads models, with restriction on maximum
    - Output = FE results, loads margin KPI
    - Sensitivity of input value to the uncertainty on the output
- **Architecture and interfaces (for both variants)**
    - **FE model**
        - Link supplier <u>FE model to logical</u> Chain Ring element in breakdown structure

        - Link bolt hole FE elements in model to interface port(s) on logical Chain Ring element
        - Link teeth FE elements in model to interface port(s) on logical Chain Ring element
    - **FE results**
        - Link the loads margin (and linked uncertainty)to the logical Chain Ring element in breakdown structure
    - **CAD model**
        - Link supplier CAD model to logical Chain Ring element in breakdown structure
        - Link bolt hole edge surfaces and in model to interface port(s) on logical Chain Ring element
        - Link teeth surfaces in model to interface port(s) on logical crank gear element
        - Link the weight and cost KPI to the logical Chain Ring element in breakdown structure
- **Requirements**
    - Loads requirements
        - “Satisfies” link from supplier CAD model to the requirement
        - “Evidence of satisfies” link from both FE results and from both margin KPI to the requirement
        - Add passed with “Quantitative Proof” to the satisfies evidence
        - Add a justification to the “passed” link pointing to the approval for the “non-extreme” assumption and to the uncertainty in the off-road margin.
    - Weight requirement
        - “Satisfies” link from supplier CAD model to the requirement
        - “Evidence of satisfies” link weight KPI to the requirement
        - Add failed with “Quantitative Proof” to the satisfies evidence
    - Cost requirement
        - “Satisfies” link from supplier CAD model to the requirement
        - “Evidence of satisfies” link cost KPI to the requirement
        - Add passed “Qualitative Proof” to the satisfies evidence
- **Proposed Trade-off study**
    - Propose a new study to investigate the trade between cost, weight, material and bolt configuration for the complete crank set
    - Justification for the study that there will be a significant decrease in weight and increase in loads margin for the chain ring, but it may have negative impact on other components in the crank set.