# Failure Mode Effect Analysis

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## ASME, Takata Airbags, Galaxy 7

- https://www.flickr.com/photos/michaeljy/3682379207/
- http://i1-news.softpedia-static.com/images/news2/samsung-galaxy-s7-catches-fire-in-a-busy-coffee-shop-508251-2.jpg
- https://www.lawyersandsettlements.com/images/articles2/Takata-deployed-airbags-article.jpg

# From Mech 223

## FMEA Process

- For a part/process, determine risk priority number (RPN):
  - Severity of effect
  - Chance of cause occurring
  - Chance of detection using a control

| Failure Mode | Severity | | Occurrence | | Detection | | RPN | Recommended Action |
|---|---|---|---|---|---|---|---|---|
| | Effect | S | Cause(s) | O | Control | D | | |
| Hose leaks | - loss of performance<br>- fluid spill<br>- uses up fluid | 5 | hose cut during assembly | 6 | None | 10 | 300 | inspect units after assembly |

# From Mech 223 Cont'd

## FMEA Process (con't)

- Next steps:
  - Implement recommended actions for failure modes with high RPN
  - Iterate -> recompute RPN

← continues

| RPN | Recommended Action | Action | S | O | D | RPN |
|---|---|---|---|---|---|---|
| 300 | inspect units after assembly | - visually inspect 100% of units<br>- pressure test 10% of units | 5 | 6 | 3 | 90 |

# How FMEA Fits in the Design Process

- A comprehensive FMEA starts with individual parts, then considers sub assemblies and finally the full assembly.

1. Identify the part
2. Identify the part's function(s)
3. For each function, identify failure modes
4. Determine the potential severity of each failure mode
5. Determine the cause of each failure mode (often more than one)
6. Determine the probability that the failure will happen in the current state of the part.
7. Identify the controls in place that are intended to detect the onset of failure and respond in time to prevent the effect.
8. Determine the probability of success of the controls

# How FMEA Fits in the Design Process

9. Calculate the RPN
10. Recommend actions to address failures, beginning with the highest RPN failures
11. Calculate the expected RPN
12. Assign actions
13. Carry out the actions and cross reference the actions to the FMEA
14. Monitor the status of each action
15. Update when a part, subassembly or assembly changes
16. At the end of the project, identify any remaining high RPN failures where actions are not complete

# Failure Mode

- **Failure Mode?**

- Think of it has how something fails to meet expected performance values.

- **Failure as defined in 223 textbook** – "noticed by end-user" *This is too simple!*
- "serious unintended negative effect on some stakeholder(s)" more appropriate.

# Severity, Occurrence, Detection

- **Severity**- how bad is the potential outcome?
- **Occurrence** – what is the chance the failure will happen for the part/system in its current form?
- **Detection**- what is the chance that the design process/implementation of a procedure will identify and effectively keep the failure from occurring?
- Ratings based on scales from 1-10 used to quantify
- Scales are not really standardized (designer has some freedom to choose; definitions for each rating and consistent application are critical)
  - generally accepted practice is to  e.g. assign severity rating of 10 for serious injury or death

# Effects, Causes and Controls

- **Effect** – potential ultimate consequence
  - May be multiple effects. Focus on the worst case first
- **Cause** – underlying reason(s) for the failure
  - May be multiple causes.
  - May take some digging to work down to the root cause
  - Understanding cause is needed to allow designer to take corrective action.
- **Control** – features already incorporated in the design, implementation procedure, etc. that reduces the chance the failure will occur in implementation
  - At early stages in the design, there may not be much in this category

# Recommended Action(s)

- Address highest RPN value first
- For early design sizing, this is your analysis “to-do” list
- Calculate the expected new RPN to gauge the effectiveness of the proposed action
- Assign action to the appropriate team member
- Monitor the status of each action
- Cross reference FMEA action to supporting analysis, (e.g. Appendix F, p F-12).

# Guidelines when Recommending Action(s)

- Consider making your design inherently safe.
- Take care to avoid “solving” problems through the use of warnings and disclaimers in the user manual.
- Beware of the temptation to over-analyze and run out of time - It may be better to be conservative with sizing, allow costs to rise and performance to suffer to make a safer design (net benefit). Apply ***Hooley’s Theorem*** (Roy Hooley UBC’47 Civil prof 1952-1996. Pioneer of FEM and Old Port Mann bridge designer)
  - Will fail
  - Won’t fail
  - Might fail – effort required

# Additional General Guidelines

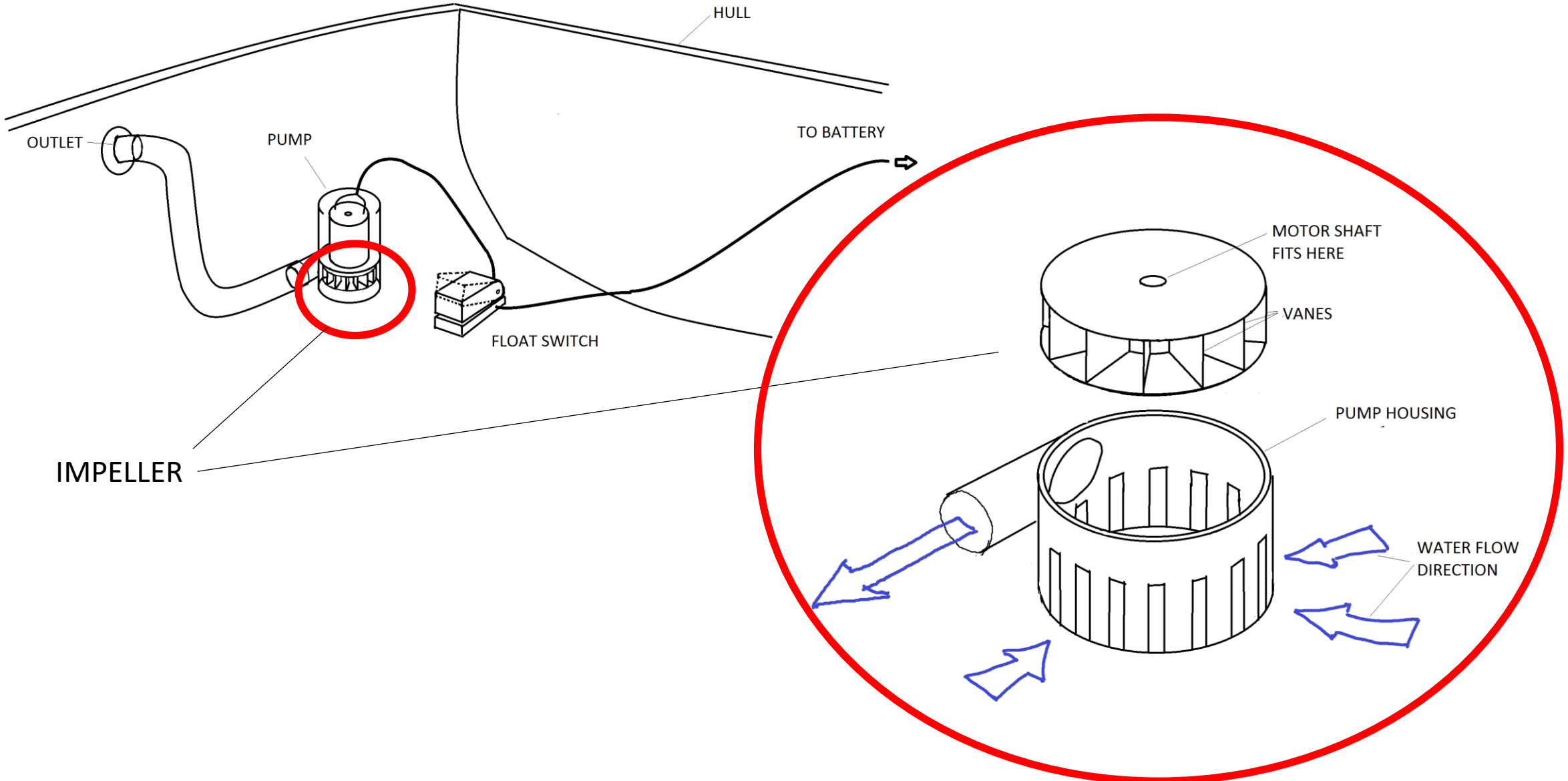
- For a Design FMEA focus on the specification and assume that
  - All parts will be made to your specifications, including custom and off the shelf parts
  - Parts are handled and assembled correctly during manufacturing and delivery (intact delivery to end user)
- If you are designing a custom part, you have to determine the actual performance
- Off the shelf parts and assemblies – trust the manufacturer's specifications for performance but beware of caveats in applications notes. You are ultimately responsible to ensure that the component's specifications meet your design's requirements – no need to do FMEA on the individual parts of an off the shelf motor, but consider failure modes of the motor assembly based on your implementation

# Expectations for Mech 328 (D)FMEA

1. Every team member should take on at least one part or assembly and perform the FMEA for that item
2. Focus on what seem likely high RPN items
3. You don’t have time to do this comprehensively – suggest stopping at 4 failure modes per item, 4 causes per FM
4. We want to see a history – early, mid and final FMEA with increasing rigour.

Thinking about failure is a chance to think creatively☺

# Example: FMEA on Bilge Pump



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Failure Modes and Effects Analysis | | | | | | | | | | Revision: | | | | | | | |
| 2 | Part | Function(s) | Failure Mode | Severity | | Occurrence | | Detection | | RPN | Recommended Action | Assigned To | Expected results of action | | | | Status of Action | |
| 3 | | | | Effect(s) | S | Cause | O | Control | D | | | | S' | O' | D' | RPN' | C=Completed P= In-Progress N=Not Addressed | Cross Reference to Appendix, Page Number |
| 4 | **Custom designed bilge pump impeller** | convert motor torque and motion to impart motion and apply load on water | impeller disconnects from shaft | boat fills with water and potentially sinks | 10 | Joint undersized for potential loads | 10 | none | 10 | 1000 | size joint for worst case load | Binky Marsden | 10 | 1 | 10 | 100 | C | App. G, p. G-8 |
| 5 | | | impeller vanes fracture and fall off | boat fills with water and potentially sinks | 10 | premature fatigue failure | 8 | annual inspection might catch crack, excessive vibration from cracked vane | 6 | 480 | size vanes for expected life | Sukram Relgnef | | | | 0 | | |
| 6 | | | impeller wears prematurely to excessive clearance | boat fills with water and potentially sinks | 10 | material abraded too easily | | | | 0 | select material that gives acceptable wear | Evets Kagor | | | | 0 | | |
| 7 | | | impeller deforms and jams | boat fills with water and potentially | 10 | poor material stability | | | | 0 | | Sir H.C. Nossekcm | | | | 0 | | |
| 8 | | | | | | temperature sensitivity | | | | 0 | | Ketyov Zcotpalk | | | | 0 | | |
| 9 | | | | | | material not stiff enough:deformation due to loading excessive | | | | 0 | | | | | | 0 | | |
| 10 | | | impeller swells | boat fills with water and potentially sinks | 10 | poor material choice; hygroscopic, incompatibility with water | | | | 0 | | | | | | 0 | | |
| 11 | | | impeller sticks to pump housing | boat fills with water and potentially | 10 | poor material compatibility with pump housing | | | | 0 | | | | | | 0 | | |
| 12 | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | |

# Failure Modes and Effects Analysis

Revision:

| Part | Function(s) | Failure Mode | Severity | | Occurrence | | Detection | | RPN | Recommended Action | Assigned To | Expected results of action | | | | Status of Action | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Effect(s) | S | Cause | O | Control | D | | | | S' | O' | D' | RPN' | C=Completed P= In-Progress N=Not Addressed | Cross Reference Appendix Page Number |
| **bilge pump system** | remove excess water faster than it comes into boat | no flow | boat fills with water and potentially sinks | 10 | intake blocked by debris | 5 | Intake screened and regular cleaning required | 5 | 250 | pick up point is raised slightly off bottom of boat to allow dense debris to collect away from input and float switch is set to allow floating debris to float above intake. | Mengus Farkler | 10 | 5 | | 0 | | |
| | | | | | output blocked | | | | 0 | | | | | | 0 | | |
| | | | | | pump rotor jammed by debris | | | | 0 | | | | | | 0 | | |
| | | | | | pump failure | | | | 0 | | | | | | 0 | | |
| | | | | | float switch motion blocked by debris | | | | 0 | | | | | | 0 | | |

# Exercise:

1. Use existing or download as templates *FMEA Example Bilge Pump Impeller, FMEA Example Bilge Pump System* (Failure, Risk and Safety Resources under Templates on Canvas)
2. Work in team to brainstorm and identify failure modes for parts of your microplastics sampling solution.
3. Take time to identify/argue the possible outcomes (severity and causes) for each failure mode.
4. Identify the occurrence and calculate RPNs
5. Prepare to be called to the front to present and discuss