Sensor Development for PEM Fuel Cell Systems
DOE Cooperative Agreement DE-FC04-02AL67615
Project No. DOE #131

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Annual Progress Review

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Program Objectives

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Task 1 – Sensor Requirements

This task will define the requirements of each of the physical sensors. The preliminary sensor requirements will be evaluated against the requirements created from the customer interviews. A broad market survey will validate the requirements and provide the inputs to the design task.

Task 2 – Sensor Development

This task will be an initial development of the Physical Sensors to demonstrate their ability to meet the necessary requirements in a laboratory environment. Several subtasks are identified to meet this objective.

Task 3 – Prototype Sensor Development

The proposed Physical Sensors developed in Task 2 shall be manufactured into operating prototypes suitable for third-party fuel cell system testing and evaluation. This includes all necessary design, fabrication, and rework necessary to meet the requirements set forth in Task 1.

Task 4 – Field Testing

It is Honeywell's position that the proposed sensors will gain technical and/or cost advantage by combining their functionality into an overall system architecture and testing them in their intended fuel cell system environment. The purpose of this task is to test and demonstrate the sensors on operating fuel cells and reformers at third-party facilities.

The technical approach for this program is to look at the fuel cell system and establish the requirements for each physical sensor, then develop packaging strategies for the sensors to minimize sensor cost. Prototype sensors will be designed, fabricated and tested in third party fuel cell systems and fuel processor companies.

Program Timeline

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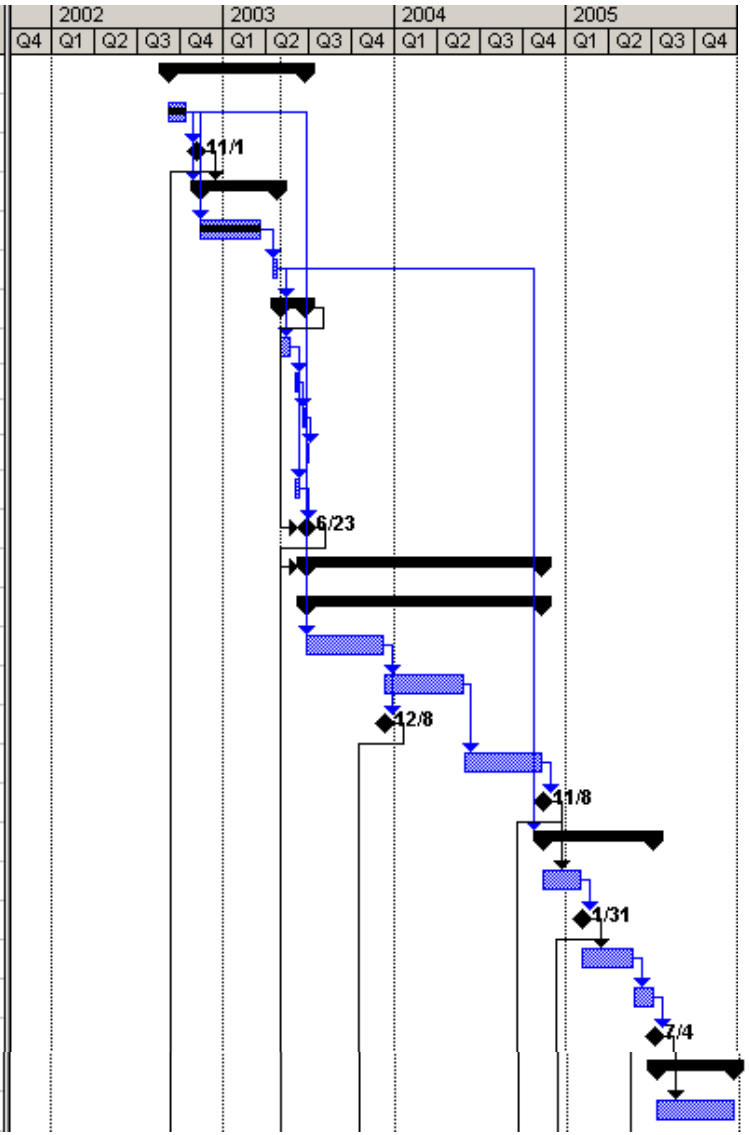
WBS	Task Name
1	**Sensor Requirements**
1.1	Preliminary Requirements Definition
MS-1.1	Preliminary Requirements Review
1.2	**Update Requirements**
1.2.1	Third Party Interviews
1.2.2	Evaluation of Third Party Requirements
1.3	**Finalize Requirements**
1.3.1	Determine sensor requirements from transcripts
1.3.2	Finalize Field Survey
1.3.3	Distribute Field Survey
1.3.4	Analyze Field Survey
1.4	Select Third Party Test Facilities
MS-1.2	Final Sensor Requirements Review
2	**Sensor Development**
2.1	**Physical Sensors**
2.1.1	Technology Concepts
2.1.2	Packaging Concepts
MS-2.1	Physical Sensors Test Plan Review
2.1.3	Preliminary Testing
MS-2.2	Physical Sensor Design
3	**Prototype Build & Test**
3.1	Fabrication
MS-3.1	Physical Sensors Demonstration
3.2	Testing
3.3	Rework
MS-3.2	Prototype Demonstration - Sensors Available for Test
4	**Field Testing**
4.1	Third Party Testing



- **Market Driven Product Definition (**MDPD®**).**
- **Why Follow a Process for Customer Visitation?**
  - Reduce risk of product not meeting customers' needs
  - Reduce dependency on individual knowledge basis and opinions
  - Discover customers' latent needs - "wows" and "delighters"
  - Establish measurable criteria
    - Ensure that product meets customer requirements
    - Use in competitive benchmarking

MDPD® Process Map

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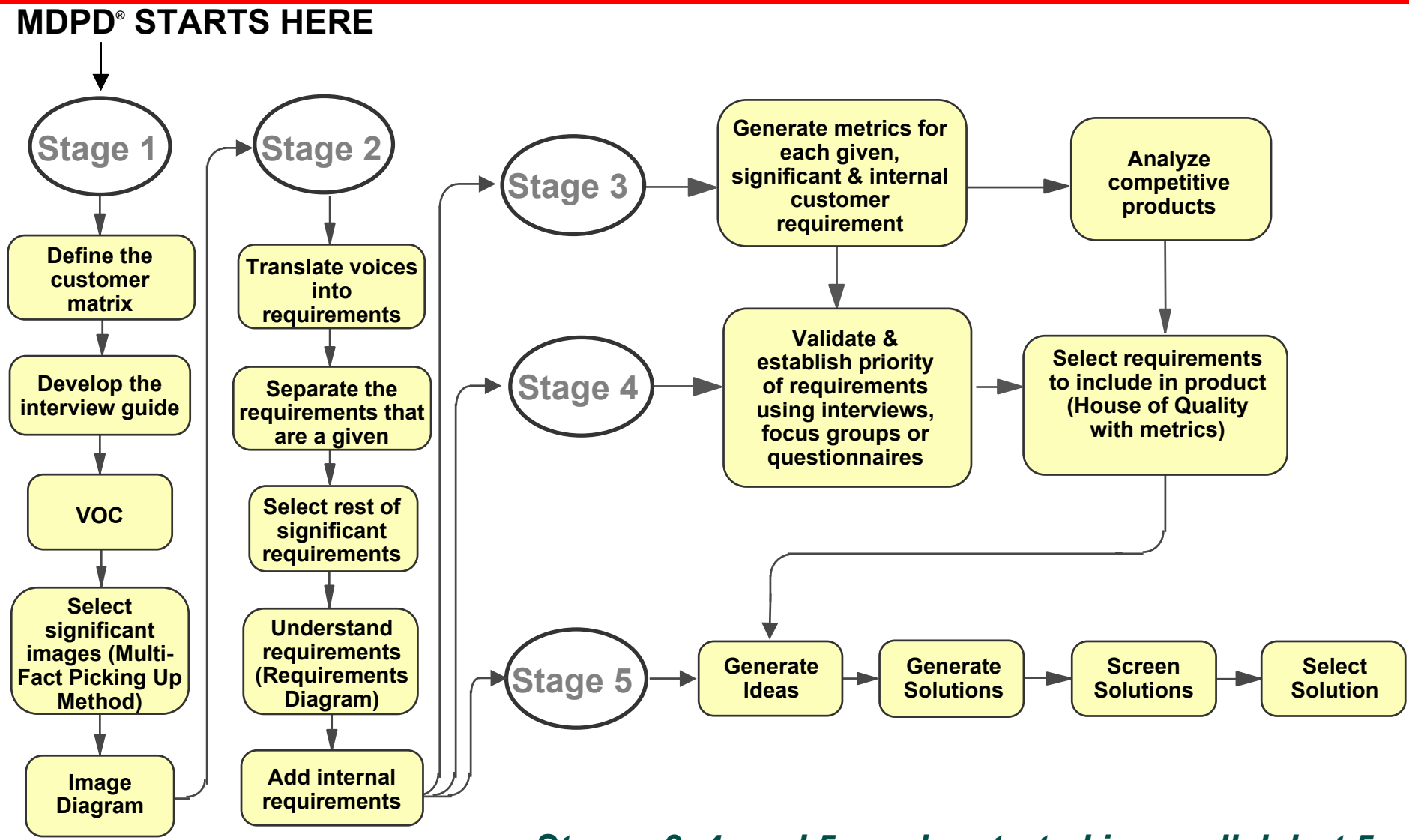
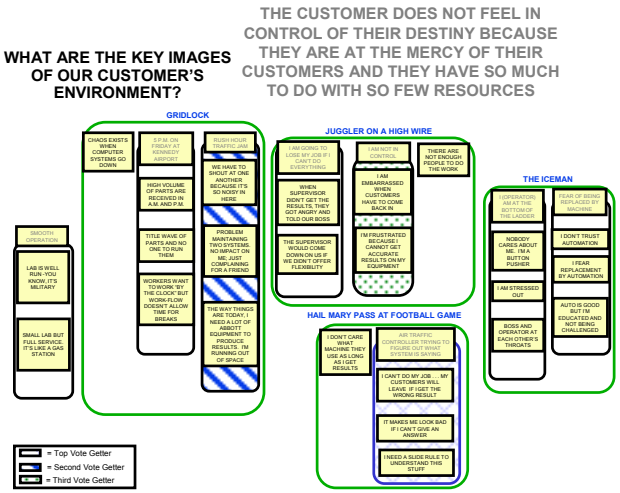


Stages 3, 4, and 5 can be started in parallel, but 5 should not be completed until 3 and 4 are done

Gather Customer Information



- The cross-functional team visits customer at customer's site
- Purpose is to listen to customer, not to sell or defend existing products
- Visit typically 12-20 customer sites
- Create a common image of the environment

Stage 1 – Interview List

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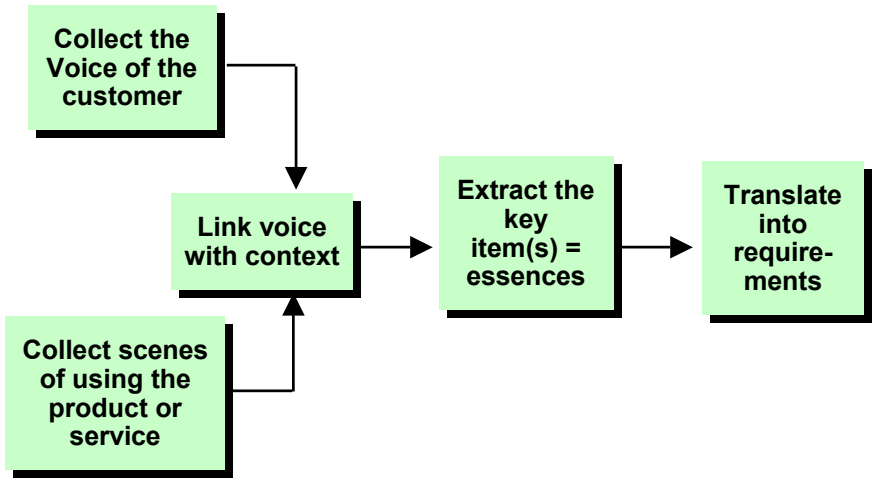
COMPANY	INTERVIEWED	LOCATION
GM	11/13/2002	Honeoye Falls
UTC	11/20/2002	Hartford
Plug Power	11/21/2002	Albany
Avista	11/27/2002 (phone)	Spokane
Nuvera	12/11/2002	Cambridge
Ballard	01/09/2003	Burnaby
H2Fuel	01/28/2003	Chicago
Ballard	02/27/2003	Nabern
DaimlerChrysler	02/28/2003	Ulm
Ford	03/18/2003	Dearborn

Identify IMAGES from the interview transcripts
Visual representation of the customers environment.

Examples:

- At start up you get big slugs of water flowing and yes that's a problem.
- We don't want big electronics hanging off these things.
- You have to be able to drive the car into a pond of water.

Develop Customer Requirements



- Link customer voices to the image to help define “delighters”
- Select key customer requirements
- Prioritize requirements

Identify VOICES from the interview transcripts
A statement of customer's need for the product.

Examples:

- Flow of humid streams has been a tough measurement.
- The head can't be any bigger than my thumb and have all the electronics.
- The connector has to be waterproof, IP67.

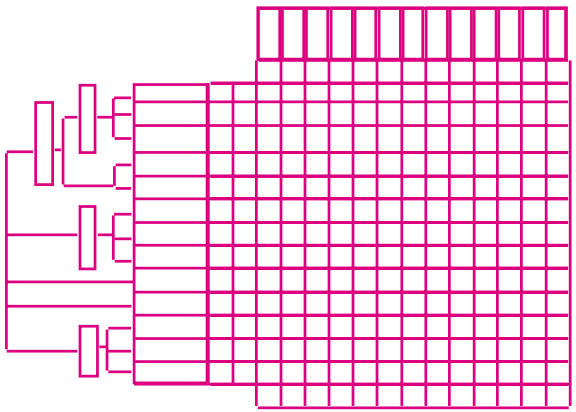
Form a requirement from the voice and linked image if any.
Examples:

• Flow of humid streams has been a tough measurement.
The sensor has to perform in condensing environments.

• The head can't be any bigger than my thumb and have all the electronics.
The sensor interface electronics must have minimal impact on size.

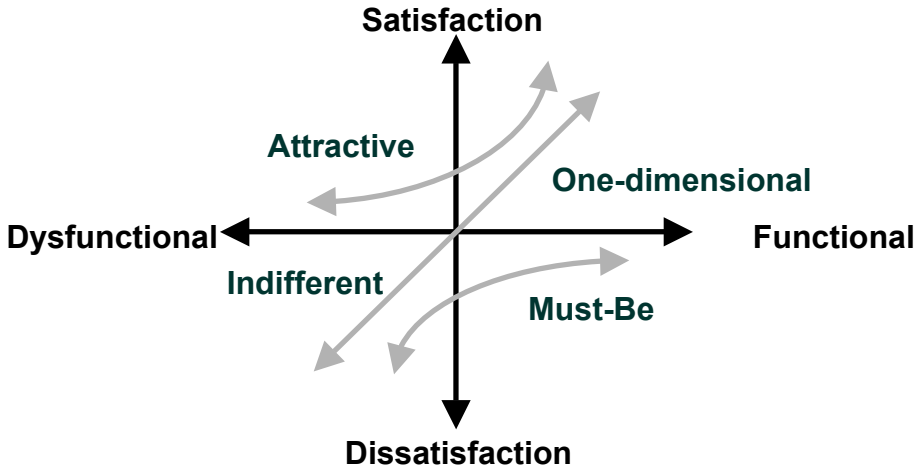
• The connector has to be waterproof, IP67.
The sensor must be sealed like an automotive sensor today.

Develop Metrics for Requirements



- Create metrics for each important requirement
- Cross-check metrics with requirements to ensure coverage and to eliminate duplicates
- Create detailed instructions for performing the measure, enabling team to ensure that requirement is met

Validate, Prioritize, and Select Requirements



- Prioritize requirements by performing a survey of broader population.
- Use Kano method to distinguish “attractive” from “must-be” requirements.
- Include all “must-be” and several “attractive” qualities, and at least as much as the competition on “one-dimensional” requirements.

Create a Kano question set for a requirement created during translation

Use this 1-5 rating system, with the exact wording...

1a. If the cellular phone continued working after being dropped on cement, how would you feel?	1. I would be delighted. 2. I would be satisfied with it. 3. I would be neutral. 4. I could tolerate it. 5. I would dislike it very much.
1b. If the cellular phone broke after being dropped on cement, how would you feel?	1. I would be delighted. 2. I would be satisfied with it. 3. I would be neutral. 4. I could tolerate it. 5. I would dislike it very much.

Example Results

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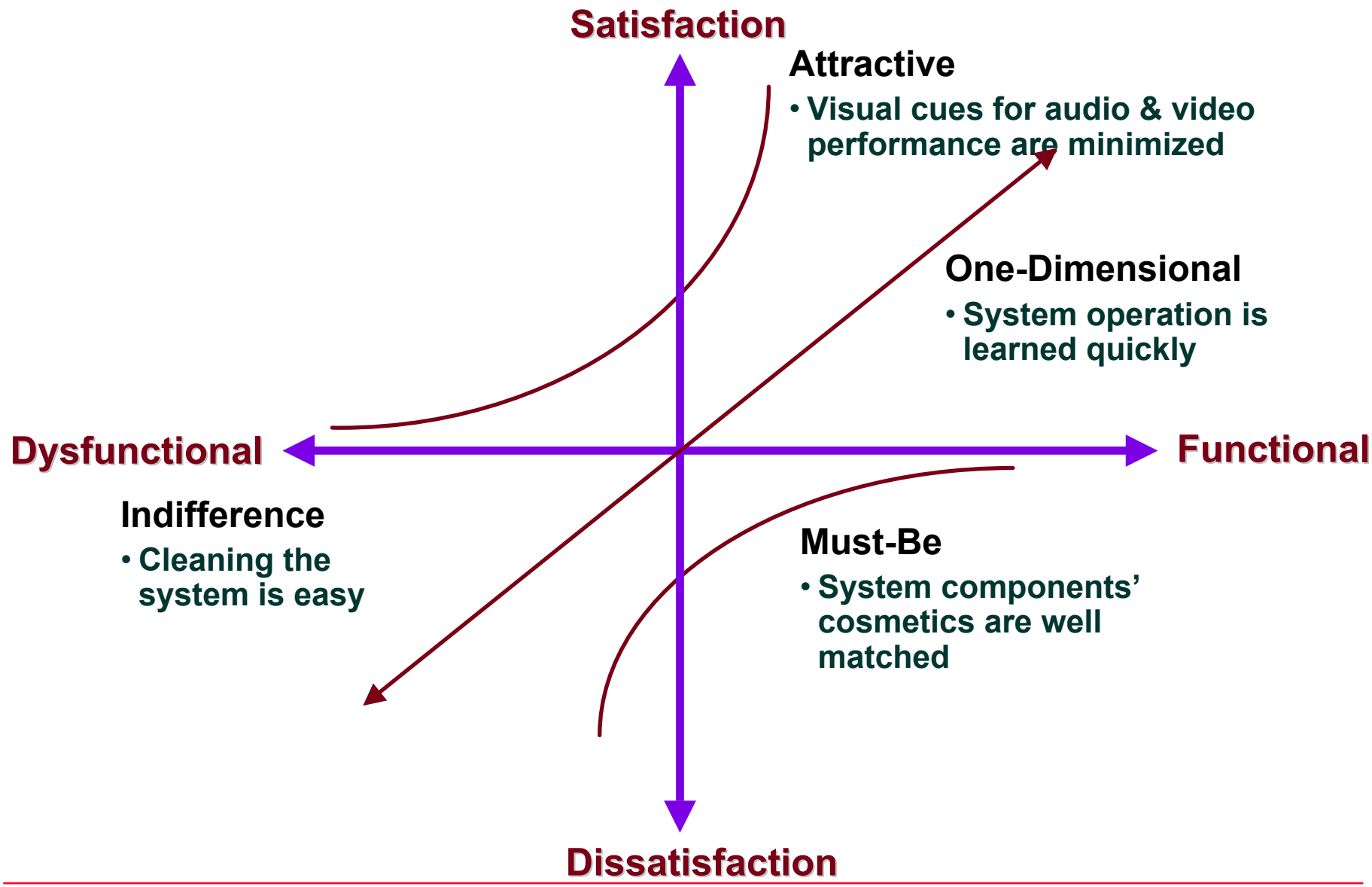
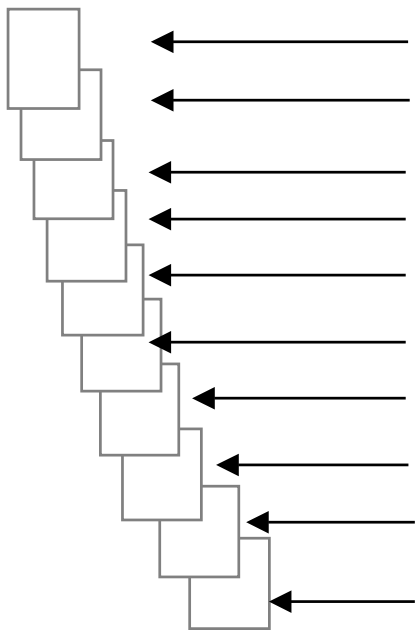


Deploy survey to the interview list plus many additional users.

Analysis of survey responses should:

- Validate requirements list
- Establish relative importance for key requirements
- Identify features that must be in the product
- Identify features that have little importance
- Identify features that are attractive
- Form the basic specification metrics needed

Generate Product Definition



- Brainstorm alternative solutions
- Select solutions that best meet requirements and better competitive offerings
- Remain within budget and market window constraints
- Document the features of the solution

Next Steps

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- Design and execute a field survey to validate the requirements and gather sensor metrics.
- Finalize sensor requirements and review with DOE.
- Brainstorm the requirements for the top 2-3 solutions for each sensor.
- Prioritize solutions.
- Create Engineering Development Specification (EDS) for top priority concept for each physical sensor.
- DOE review and approval of EDS.
- Begin sensor development.

- General
  - Meeting cost targets.
- Relative Humidity Sensing
  - Stability over application life.
  - Ability to provide feedback in two phase flow.
- Flow Sensing
  - Providing a stable, accurate output in non-condensing and condensing environments.