Constraints: Bounds/limits on the solution space that make it acceptable to the customers. They reduce the solution space. (Customer Needs Constraints and FRs Lecture, Jan. 9)

Identify Customers:

- NASA
- The Launch Provider
- Suppliers of the Instruments
- Testing Facilities
- Congress
- The public

Collect VOCs (Voice of Customer – Expectations and Feedback from Customer):
Short Description/definition
Voice of Customer Expectations and Feedback represent the objectives and outcomes that customers expect from the mission. These expectations are probably based on the Mission AO, and customers will then give feedback to the PI based on their own individual wants/needs.

- List at least 3 examples from the InSight Mission.
- Each phase of the mission will occur within the allotted timeframe for that phase (the mission will be on-schedule). For InSight, the mission was initially scheduled to launch in March 2016.
- The mission will cost no more than the cost-capped amount set forth at the beginning of the mission. For InSight, this was $425M.
- The mission will return valuable scientific data to the scientific community. For InSight, this means that it would return Mars seismic data from the SEIS experiment, motion of Mars's axis from the RISE experiment, and internal temperature data from the HP3 experiment.

Analyze Needs:
List ONE need from THREE different stakeholders/customers regarding the InSight Mission

- NASA – InSight must land on Mars.
- Instrument Suppliers – The chosen instruments must be manufacturable.
- The Launch Provider – InSight must be light enough and small enough to launch.

Populate Constraints:
List at least THREE different constraints

- From NASA: The mission must be under $425M (initial cost-capped budget)
- Launch Provider – InSight must fit within the payload fairing, with a diameter of 4.2m and max height of 11m.
- Public – InSight must increase public interest in space and Mars.

Populate Customer Needs:
List three customer needs (the needs should come from NASA)

- Help NASA determine whether life ever existed on Mars.
- Help NASA determine the evolution of the surface and interior of Mars.
- Help NASA to prepare for human exploration on Mars.

Customer Needs: A list of needs and desires in the language of the customers (Customer Needs Constraints and FRs Lecture, Jan. 9)

Map Top FRs: Relate your needs to FR's (remember to use appropriate requirement language)

- InSight must be able to measure the vibrations caused by the internal activity of Mars to illuminate the properties of the crust, mantle, and core. (https://mars.nasa.gov/insight/spacecraft/instruments/summary/)
- InSight must be able to take Mars' temperature to reveal how much heat is flowing out of the deep interior of the planet. (https://mars.nasa.gov/insight/spacecraft/instruments/summary/)
- InSight must be able to measure the wobble of Mars' north pole as the Sun pushes and pulls it in its orbit. (https://mars.nasa.gov/insight/spacecraft/instruments/summary/)

Functional Requirements: A list of functions (in solution free space) that if implemented satisfy the customer needs.

Decompose Level: (Jan 9 Lecture)
Define /Explain why this is important
Design decomposition is understanding how your design parameters satisfy your functional requirements by going through each parameter to understand how it satisfies a requirement. This is important to do requirement-by-requirement and parameter-by-parameter to understand the impact of each parameter on each requirement.

Examples from InSight:
FR1: InSight must be able to measure the vibrations caused by the internal activity of Mars to illuminate the properties of the crust, mantle, and core.
DP1: InSight will be equipped with a seismometer to measure vibrations caused by internal Martian activity.

FR2: InSight must be able to take Mars' temperature to reveal how much heat is flowing out of the deep interior of the planet.
DP2: InSight will be equipped with a temperature probe to measure the internal temperature of Mars.

FR3: InSight must be able to measure the wobble of Mars' north pole as the Sun pushes and pulls it in its orbit.
DP3: InSight will have a radio instrument to measure exact position and wobble of Mars.

Check Constraints (Jan 9 Lecture): Define/Explain why this is important
Checking Constraints is verifying that the design parameters do not violate the constraints on the mission. This is important because design parameters are not allowed to violate constraints, by the definition of a constraint.

Examples (continued from above):
CON1: The seismometer will be able to measure seismic activity to +/- 0.01 on the Richter Scale. The constraint is not violated by DP1.

CON2: InSight will be able to measure temperature ranges from 10K – 500K. This is outside the scope of available temperature probes, so either FR2, DP2, or CON2 will need to be modified.

CON3: The power budget of the radio instrument is 50W. The constraint is not violated by DP3 because radio instruments with this power budget exist.

Design Matrix: Define/Explain why this is important
A design matrix is a chart or matrix relating Customer Needs to Functionality Requirements to Design Parameters. The relationships across the various design domains allows the designer to understand the impact of a design decision on the overall design. (Customer Needs Constraints and FRs Lecture, Jan. 9) A design matrix often comes in the form of a table (582) or a Pugh Matrix (583).

Examples:
CN1 -> CON1 -> FR1 -> DP1
CN2 -> CON2 -> FR2 -> DP2
CN3 -> CON3 -> FR3 -> DP3
(The needs, constraints, requirements, and parameters don't really overlap much)

Review Needs: Define/Explain why this is important
Reviewing the Needs of the Customers ensures that if any constraints, requirements, or design parameters have changed throughout development that the needs of the Customers are still being met.

Examples (continued from above):
DP1 meets FR1 and does not violate CON1. CN1 has not changed, so this review is complete.

DP2 violated CON2, so DP2 changed slightly to accept temperature range from 50K – 400K. We review this with customers, who determine that DP2 still meets CN2.

DP3 meets FR3 and does not violate CON3. CN3 has not changed, so this review is complete.

Iterate if Needed: Define/Explain why this is important
Iterating is important to do if customer needs have changed or if design parameters do not meet customer needs, as determined in the previous "Review Needs" step. If all design parameters meet current customer needs, then no iteration is necessary. If customer needs have changed or if design parameters don't meet customer needs, then CNs, FRs, CONs, and DPs may need to change (iterate).

Examples (continued from above):
As determined in the previous box no iteration of DP1 is necessary.

DP2 violated CON2, so DP2 was iterated to a point where it met CON2. At this point, CN2 was reviewed and determined that the new DP2 met CN2. Therefore iteration of DP2 is complete.

As determined in the previous box no iteration of DP3 is necessary.

Solution Set: The solution set is the group of mission designs that have been developed to satisfy the needs, requirements, and constraints of the mission. FRs and solutions have been linked in the "Decompose Level" box (each DP is a solution).

Trade Studies: Define/Explain why it is important (Wednesday's Lecture)
Trade Studies are comparisons of various potential design decisions that satisfy one or more Customer Needs, Functional Requirements, and/or Constraints. Trade Studies often weigh factors that are most important to a design, such as cost, mass, and schedule.

Examples, continuing from Column 2 (TS = Trade Study):
TS1: SEIS instrument measuring larger magnitude seismic activities vs. higher precision seismic activities.

TS2: The temperature probe measuring a larger range of temperatures vs. more precise temperature measurements.

TS3: The radio instrument consuming more power (higher power budget), or having slower/less efficient data transmission.

Risk Assessment: Define/Explain why it is important – Mention techniques to do this
Risk Assessment is determining the potential situations that pose the highest risk to the mission, and assigning them a priority based upon factors such as probability, severity, cost, schedule, etc. Risk Assessment can be done in a table, with one risk per column and one rating per column, or in a Risk Matrix which can be color-coded.

FMEA Analysis: Define/Explain why it is important – Mention tests that can be performed based on your FR's
FMEA stands for Failure Mode and Effect Analysis. It is the study of potential failure modes of the spacecraft or mission as a whole, and how those failures can affect other aspects of the mission. FMEA differs from Risk Assessment in that FMEA studies only the risks associated with a failure in the mission.

Tests based on FRs:
FR1: Unit tests of the seismometer, such as vacuum and thermal testing. System tests of the SEIS instrument installed on the spacecraft.

FR2: Unit tests of the temperature probe, such as vacuum and thermal testing. System tests of the temperature probe installed on the spacecraft.

FR3: Unit tests of the radio instrument, such as vacuum and thermal testing. System tests of the radio instrument installed on the spacecraft.

Cost Analysis: Define/Explain why this is important. Mainly monetary but mention how other budgets might affect it.
Cost analysis is determining the estimated cost of mission development and the mission itself. It can encompass small aspects of the mission but eventually will be performed on the entire scope of the mission to determine whether there remains sufficient funding for the mission.

Cost analysis can affect other budgets besides monetary budgets. For instance, oftentimes longer mission development results in higher costs, so cost analysis can affect the duration of a mission development cycle. Cost also affects the purchase of spacecraft components, which affects things like power and communications budgets.

Traceability: Define and give example of tracing:
Science Objective -> Measurements -> Instrument -> Functional Requirement -> performance requirements or operational specifications

Traceability is understanding the process of how a mission goes from initial conception to final design, and involves all aspects of mission design from customer needs to functional requirements to constraints to design parameters. Traceability is often done in the form of a matrix or mapping, with a row for each functional requirement and columns for things like unit testing, test cases, verification, validation, and status.

An example of traceability is the following path:

1. Science Objective/Customer Need: Help NASA determine the evolution of the surface and interior of Mars.
2. Measurement: Measure seismic activity on Mars.
3. Instrument: Seismometer.
4. Functional Requirement: InSight must be able to measure the vibrations caused by the internal activity of Mars to illuminate the properties of the crust, mantle, and core.
5. Design Parameter: InSight will be equipped with a seismometer to measure vibrations caused by internal Martian activity.

Process Variables: Process variables are characterizing what manufacturing methods or tests you would use for developing a solution set. For example, unit testing of each individual instrument on InSiht would be extremely useful (vacuum & thermal testing). Then run system tests on InSight to test full functionality of the spacecraft.