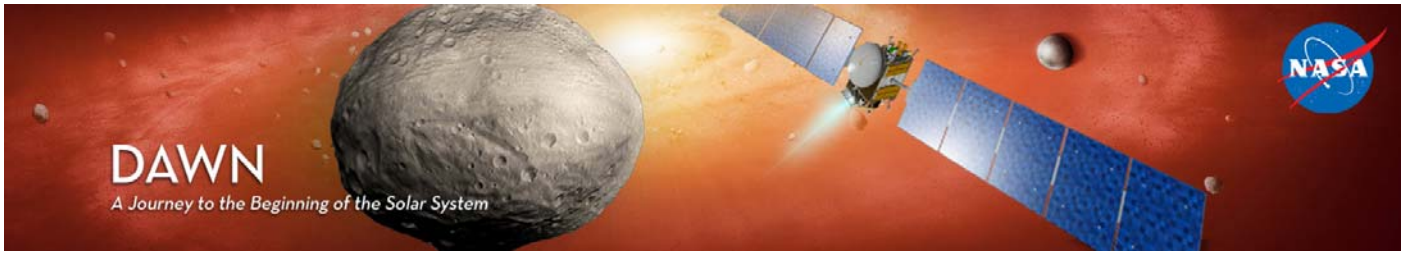



**Interaction of Energy and Matter: Dawn Instrumentation**

# Concept Maps:
## EMR Matter-Energy Interactions and Relationships

TEACHER GUIDE

This activity is designed to culminate the *Interaction of Energy and Matter: Dawn Instrumentation* module and to assess your students' understanding of the matter and energy interactions and relationships presented in the following *Interaction of Energy and Matter: Dawn Mission Instrumentation* PowerPoint presentations:

- *Framing Cameras*
- *VIR*
- *GRaND*

and in the following Student Activities:

- *Gravity Measurement: Using Doppler Shifts to Measure Mass Concentration*
- *Mineral Identification.*

We saw in the *Mineral Identification* activity that when information from the three Dawn instruments and the Radio Communications System are combined, we can learn more about the asteroids' surface mineral composition and the spatial distribution of those minerals. This information can also give us some indication of surface modification and the ages of these surfaces. When this information from Vesta and Ceres is compared with what is already known of Solar System origins, it either will substantiate current scientific thinking about asteroid origins and geologic processes or it could form the basis for new theories.

**Materials**

- Blank paper—depending upon the needs of your students, this can either be 8.5x11 sheets, poster paper, or butcher paper
- Colored pencils or markers
  *Optional:* Computers with drawing software and word-processing applications
- Copies of the *Concept Maps: EMR Matter-Energy Interactions and Relationships* Student Activity sheet
- Copies of the list of terms you want to assign (found in Procedure 1 below)
- Copies of the *Concept Maps: EMR Matter-Energy Interactions and Relationships* Student Activity sheet you have selected for this assignment—either the *CSI Concept Map: Constructing Concept Maps* or the *Concept Maps: EMR Matter-Energy Interactions and Relationships*
- Student handouts and activity sheets that your students completed as they viewed the *Dawn Instrumentation* PowerPoint presentations and their completed Student Activities. (These activity sheets should have been saved for students' use in this assessment activity.)

**Assessment Activity Assignment**

I. Using the terminology list that you assign, students will design a concept map that shows:
   - the interactions of electromagnetic radiation with the instruments aboard the Dawn spacecraft, and
   - how the analysis of the data from these interactions will help meet the objectives of the Dawn Mission.

II. Students will also write a short narrative and/or make an oral presentation that explains:
   - the relationships/interactions shown in their maps, and
   - how their maps illustrate the way in which these interactions will help meet the objectives of the Dawn Mission.

**Assessment Activity Procedure**

1. Distribute copies of the Student Activity Sheet and copies of the list of terms you want to assign. The terminology lists, A-C, reflect increasing levels of difficulty and detailed features.
   - You may use the Basic List A as a practice assignment involving the whole class and then have individuals or small groups add to the basic concept map using additional terminology from lists B and C.
   - You may also elect to match terminology lists with student abilities, giving most of your students the Basic List A and challenge more advanced students with the Origins List B or the Science/Technology List C.
   - You may also design and assign your own list by selecting the terminology from these lists.

   A. The *List of Dawn Instrumentation: EMR Matter-Energy Interactions and Relationships Concept Map* contains only the
      - basic functions of the Dawn Instrumentation Payload,
      - the range of EMR that each will analyze, and
      - the kind of information resulting from that analysis.

      The EMR included here is reflected from, originates in, or results from the composition of the protoplanet surface. This list is most appropriate for middle school and general physical science students.

      Albedo
      Chemical element identification/concentration
      Framing Cameras
      Gamma Rays
      GRaND
      Infrared Reflectance
      Radio Communications System
      Radio waves Doppler Shifts
      Spatial Distribution of Minerals
      Surface Mineral Composition
      Surface Mineral Identification
      Surface Mass Concentration map
      Surface topography mapping
      VIR
      Visible EMR Reflectance

You will find the accompanying examples for mapping these terms using the above procedure on pages 9-11.

   B. The *Origins of EMR Matter-Energy Interactions and Relationships Concept Map* includes the Basic List above plus terminology that describes:
      - the *origins* of the gamma rays and neutrons detected by GRaND, and
      - the *causes* of the Doppler Shifts detected by the Radio Communications System.

      Since these sources are different from EMR reflectance detected by the Framing Camera and VIR, this list is appropriate for students who have some background in these physical science concepts.

      Albedo
      BGO Sensor
      Changes in Line of Sight Velocity
      Chemical element identification/concentration
      Cosmic Rays
      CZT Sensor
      Framing Camera
      Gamma Rays
      GRaND
      Infrared Reflectance
      Mass concentration change

Neutrons
    Fast/Thermal/ Epithermal
Radio Communications System
Radio Waves Doppler Shifts
    Red shift/Blue shift
Spacecraft instrumentation payload
Spatial Distribution of Minerals
Surface Mass Concentration Map
Surface Mineral Composition
Surface Topography Mapping
Surface Mineral Identification
VIR
Visible EMR Reflectance

You will find the accompanying examples for mapping these terms using the above procedure on pages 12-15.

C. In addition to the prior lists, the *Science and Technology of EMR Matter-Energy Interactions and Relationships Concept Map* includes terminology specific to the *internal processing* of matter and energy interactions in the Dawn Instrumentation. These additional terms are appropriate for students with physics and technology backgrounds.

Albedo
BGO Sensor
    Gamma Rays from Volatile/ Stable Elements
Changes in Line of Sight Velocity
Charge coupled device (CCD)
Chemical element identification/concentration
Cosmic Rays
CZT Sensor
Gamma Rays from Radioactive Elements
Data processing unit (DPU)Framing Camera
Filter wheel
4-lens optical system
Gamma Rays
GRaND
High Altitude Mapping Orbital (HAMO) Optical mapping
Infrared Reflectance
Low Altitude Mapping Orbital (LAMO) Optical mapping
Mass concentration change
Navigation function
Neutrons
Fast
Thermal
Epithermal
Offner spectrometer
Diffraction grating
Visible EMR
Infrared EMR
Infrared Focal Plane Array (IRFPA)
Radio Communications System
Radio Waves Doppler Shifts
    Red shift
    Blue shift
Shafer telescope
Aluminum and beryllium mirrors
Spacecraft instrumentation payload
Spatial Distribution of Minerals
Surface Mass Concentration Map
Surface Mineral Composition

Surface Topography Mapping
Surface Mineral Identification
VIR
Visible EMR Reflectance

You will find the accompanying examples for mapping these terms using the above procedure on pages 16-19.

2. Explain to students whether they will be working individually or in groups to design a concept map that shows the relationship between the items or objects listed on the activity sheet. These terms should not be new to them if you have used the Dawn PowerPoint presentations with your class.

   They will also be writing a short narrative and/or making an oral presentation that explains:
   - the reason for their arrangement of the terms in the concept map,
   - the relationships/interactions shown in their maps, and
   - how these maps illustrate the interactions that will help meet the objectives of the Dawn Mission.

   Students should have the option of completing the concept map or the narrative in the order of their preference, or they can work on the two parts of the assignment concurrently.

   Tell them that they may use the Student Handouts that they completed as they watched each of the PowerPoint presentations as well as their completed *Gravity Mapping: Measuring Mass Concentration* and *Mineral Identification* activity sheets. You may also want to make the *Dawn Instrumentation* PowerPoint presentations accessible for student review if you have computers available for their use.

   At this time, you will also want to tell students whether you will be evaluating their written narratives, their oral presentations, or both. You may also tell them that you will be looking for correct understandings and accurate representations of matter-energy interactions and relationships in both their concept map and their descriptive narrative.

3. If your students have not had the experience of designing a concept map, you have two options for scaffolding this assignment.
   a. Use the terms list selected, help your students work through the following procedure as a class. Each student or group of students should make their own decisions.
      i. Decide which of the terms or processes is the most fundamental or plays the central role in the concept you are mapping.
      ii. Classify the remaining terms into at least two groups based on either their properties or their functions.
      iii. Which of the groups relates the most closely to the central role? Continue this step until you have included all the groups.
      iv. Decide on shapes and colors of symbols that will represent each of the groups you have classified.
      v. Start your map by placing the symbols that represent the central group in the center of the map. Use arrows (which may be color coded to match the symbols) to represent relationships between these items or objects.
      vi. Add symbols representing other terms or objects and adding as many arrows as you can that represent the relationship between that symbol and those representing other terms and objects.
      vii. Write the narrative that explains your concept map.

   b. If you feel your students need more practice in constructing concept maps before completing this assessment section, we have included a mapping activity with a list of terminology related to the CSI activity from the Briefing Section of this module. The Teacher Guide accompanying this activity contains example answers to the guided instructions (i-vii above) for constructing concept maps.

4. Evaluating student concept maps.
   Examples of the following are shown for each of the three terminology lists on the indicated pages:
   - classification, shape and color coding of the given terms, pages 9, 14, and 18 and
   - a sample concept map containing these terms, pages 11, 15, and 19.

   Remember that there are many ways to construct concept maps. Although the relative placement of some of the terminology is important, the relationship lines or arrows between the items are even more important as you assess student understanding of the concepts. You should look for misunderstandings or misrepresentations in the groupings, interactions and relationships so that you can help students correct these errors in the follow-up discussion.

5. Evaluating the narrative.
   Narrative outlines that indicate the grouping, interactions, and relationships shown in each map and an explanation of how these groupings, interactions, and relationships will help meet the objectives of the Dawn Mission are found on pages 10, 13, and 17.

   Again, remember that there are as many different ways to explain the relationships shown in concept maps as there are students or groups of students constructing the maps. As you assess both the map and the narrative be aware of misunderstandings or misrepresentations in the groupings, interactions, and relationships so that you can help students correct these errors in the follow-up discussion.

   You may wish to use a rubric like the following to evaluate your students' work.

| Rubric for Evaluating the Dawn Instrumentation Matter-Energy Relationships | | | | |
|---|---|---|---|---|
| Rubric characteristics/point values<br>4 - Both concept map and narrative show student has a complete and detailed understanding of the concept (a–e) for the Dawn instrument being considered.<br>3 - The concept map [or narrative] shows a complete understanding of the specific concept (a–e) *but* the narrative [or concept map] contains some incomplete understandings relating to the Dawn instrument being considered.<br>2 - *Both* the concept map and the narrative contain incomplete understandings or misconceptions of the specific concept (a–e) relating to the Dawn instrument being considered.<br>1 - The concept map and the narrative are both so incomplete or have so many misconceptions regarding specific concepts (a–e) that there is question about the student's understanding of this concept as it relates to the Dawn instrument being considered. | | | | |
| Dawn Instrumentation<br>Concept(s) being mapped | Framing Cameras | VIR Spectroscope | GRaND | Radio communication system |
| a. the <u>interactions</u> between EMR and the instrument | | | | |
| b. the <u>analysis and presentation</u> of the processed data | | | | |
| c. the <u>significance of this processed data</u> as related to the Dawn Mission objectives | | | | |
| d. For concept maps 2 and 3, <u>sources of EMR</u> other than reflectance | | | | |
| e. For concept map 3 only— the <u>instrument's internal processing</u> of EMR | | | | |
| The narrative and/or presentation explains relationships and/or interactions shown in the concept map not included in concepts a-e above. | | | | |

6. Follow-up discussions. After students have completed the assignment and you have evaluated their work, the follow-up class discussions should include:
   a) Using guided questions similar to the following to clarify and correct misunderstandings or misrepresentations in the concept map or narrative.
      i. If the student(s) selected a questionable "fundamental" term, ask "Why did you select this/these term(s) as your fundamental terms?" or "In what way do you see this/these term(s) as being more fundamental than the others listed?"
      ii. If the student(s) placement of a term is questionable, probe the student's reasoning for placement starting with, "How do you define the term, ___ (the one in question)?" Then, "This term may also be defined as_____. Does your placement of the term in the concept map reflect this definition of the term?"
      iii. If a relationship arrow is questionable, ask, "What relationship the does the arrow going from ___ to ___ indicate?" If the student response indicates an understanding that is not shown in the concept map, follow up with a question like, "Is there another way that you could have shown this more clearly?"
      iv. If there appears to be a misunderstanding of the relationship between a specific instrument and its contribution to a Dawn Mission objective, ask, "In what way do you think that this instrument contributes to this Dawn Mission objective?" and/or "Does this instrument contribute to any other Dawn Mission objective? "Are there any other instruments that contribute to this objective?"

   b) A discussion about how this information will meet the immediate objectives of the Dawn Mission—to increase our knowledge of the asteroids' surface mineral composition and the spatial distribution of those minerals and give us some indication of surface modification and the ages these surfaces.

   c) Remind students that the presence or absence of water and the soil silicate content was important to the CSI team as they analyzed the crime scene in the Dawn Briefing Activity. The presence or absence of these compounds in Vesta's and Ceres' surface features are also important to the Dawn mission scientists. Space scientists think that Vesta is a dry, rocky asteroid whereas Ceres may have frozen water (water ice).

      Say, "So, one of the objectives of the Dawn mission is to search for ices near the asteroids' surfaces. When we use the term "ice" we usually mean the solid form of water. Space scientists often use the term "ices" to indicate the solid form of carbon dioxide, ammonia, and other compounds that are gases in our environment as well as solid water."

      Ask students, "What chemical elements would scientists have to identify to determine whether or not these ices are present in the surfaces of Vesta and Ceres?"
      [carbon dioxide-carbon and oxygen; ammonia-nitrogen and hydrogen; water ice-hydrogen and oxygen]

      Continue by asking, "Which of the instruments in the Dawn payload could give us this information?"
      [GRaND or VIR would be the most useful in determination of the presence of these elements.]

      Then ask, "What characteristic of matter makes it possible for GRaND and VIR to identify elements and compounds and their percentage compositions remotely?"
      [The answer is found in the textbox.]

**Interactions of Energy and Matter**
**Standard Connection**

Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.

7. Segue into Curriculum Module #4: Origins.

   Say something like the following: “Scientists are anticipating that when the new Dawn information is compared with what is already known about the origin of the Solar System, their findings will either substantiate current scientific ideas about asteroid origins and geologic processes or it could form the basis for new ideas and understanding.”

   Then ask, “How will the Dawn scientists know whether or not the new Dawn data substantiates current hypotheses or whether or not we will need to form new hypotheses and conclusions?”

   This question should prompt students to ask what the current hypotheses are and how the information from the Dawn Mission supports or negates the current ideas. You may tell them that the information and activities that are part of the Dawn Content Module 4 will help them analyze what properties of asteroids support and/or contradict aspects of these hypotheses as they continue their study of “Origins.”

   Or you may want to incorporate the following optional activity.

   **Optional Activity**
   Have students do an Internet search using keywords like “ Solar System origins” or “ Asteroid origins” to answer their questions. They will most likely find one or more of the following models or theories in response to their search:

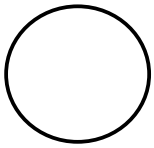
   Accretion Model
   Perturbation Model
   Failed-Planet Model
   Nice Model
   Planet Fragmentation
   Condensation Theory

   Have them report back the main points in each of the models and/or use the information and activities that are part of the Dawn Content Module 4 to analyze what properties of asteroids support and/or contradict aspects of these models as they continue their study of “Origins.”

**Terms to include in the *Dawn Instrumentation: EMR Matter-Energy Interactions and Relationships Concept Map***

Albedo
Chemical element identification/concentration
Framing Cameras
Gamma Rays
GRaND
Infrared Reflectance
Radio Communications System
Radio waves Doppler Shifts
Spatial Distribution of Minerals
Surface Mineral Composition
Surface Mineral Identification
Surface Mass Concentration map
Surface topography mapping
VIR
Visible EMR Reflectance

**Examples of shape and color coding for classification of terms and objects**



Black Circle-Dawn Instrumentation Payload

Black rectangle- Dawn Spacecraft Instrumentation

Gray rectangle - Radio Communications System

Red rounded rectangle – Range of EMR interacting with instrumentation

Blue trapezoid-Result of instrument analysis of matter-energy interactions

Green rounded rectangle-Dawn Scientific Objective accomplished

## Narrative Outline Example

Example of a narrative outline that indicates the grouping, interactions, and relationships shown in the map are included in the following page and how this map explains how these interactions will help meet the objectives of the Dawn Mission

*VIR-Visible and Infrared Imaging Spectrometer*

VIR uses visible and infrared reflectance from the surface of the asteroids to

- determine the mineral composition of surface materials and
- their spatial distribution

*Framing Camera*

Framing Cameras use reflectance of visible EMR from the surface of the asteroids to

- measure the surface albedo
- map surface topography

*GRaND*

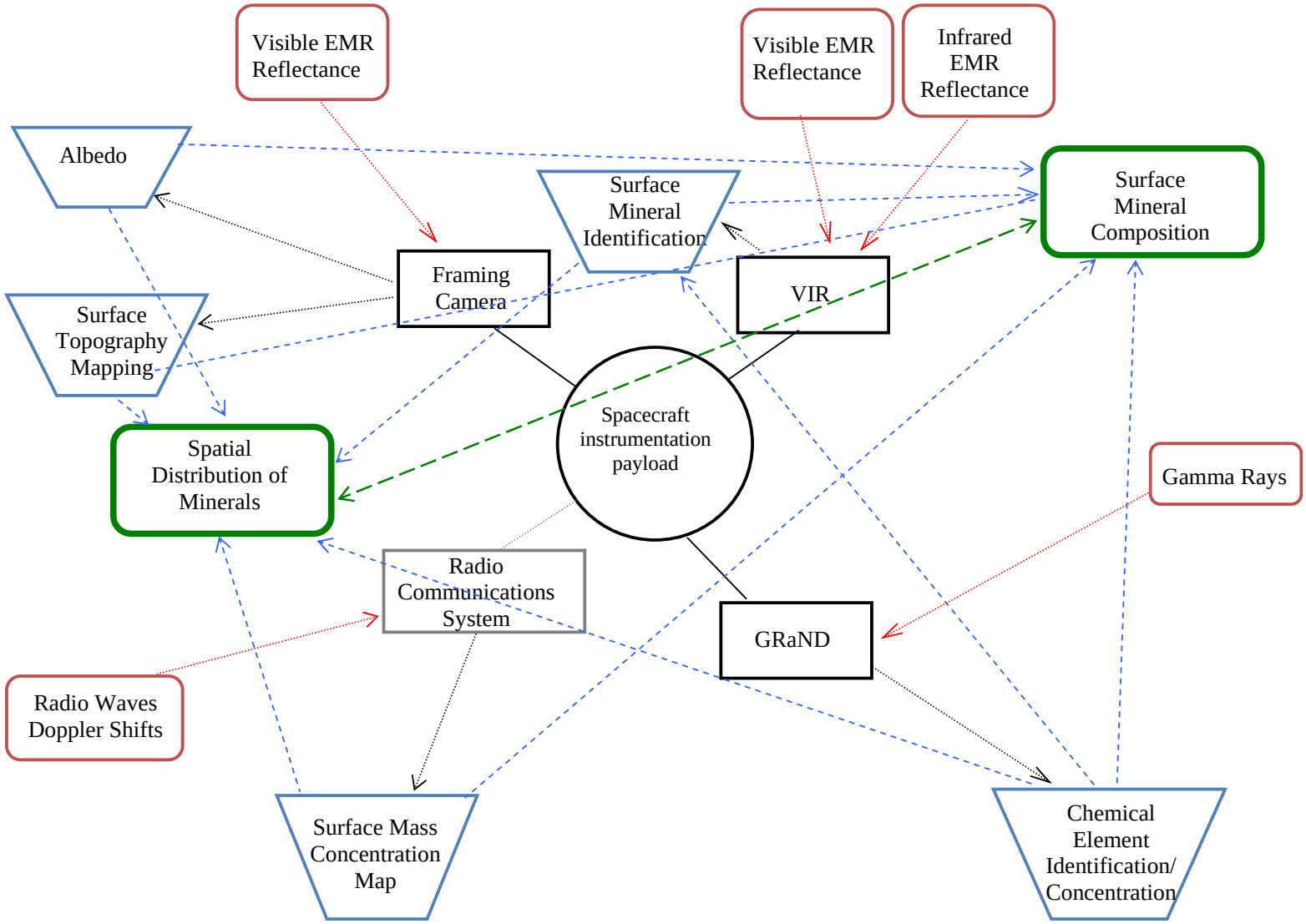
GRaND intercepts gamma radiation from decay of radioactive elements in the asteroids' surface to

- measure the concentration of radioactive surface elements

The Radio Communications System will detect changes in radio wave frequencies (Doppler shifts) to form a mass concentration map of the asteroids' surface.

When information from the three Dawn instruments and the Radio Communications System are combined, they will increase our knowledge of the asteroids' surface minerals and the spatial distribution of those minerals.

**Sample Concept Map Dawn Instrumentation: EMR Matter-Energy Interactions and Science Objectives**



**Terms to include in the *Origins of EMR Matter-Energy Interactions and Relationships Concept Map***

Albedo
BGO Sensor
Changes in Line of Sight Velocity
Chemical element identification/concentration
Cosmic Rays
CZT Sensor
Framing Camera
Gamma Rays
GRaND
Infrared Reflectance
Mass concentration change
Neutrons
    Fast
    Thermal
    Epithermal
Radio Communications System
Radio Waves Doppler Shifts
    Red shift
    Blue shift
Spacecraft instrumentation payload
Spatial Distribution of Minerals
Surface Mass Concentration Map
Surface Mineral Composition
Surface Topography Mapping
Surface Mineral Identification
VIR
Visible EMR Reflectance

## Narrative Outline Example

Example of a narrative outline that indicates the grouping, interactions, and relationships shown in the map are included in the following page and how this map explains how these interactions will help meet the objectives of the Dawn Mission

*VIR-Visible and Infrared Imaging Spectrometer*

VIR uses visible and infrared reflectance from the surface of the asteroids to

- determine the mineral composition of surface materials and
- their spatial distribution

*Framing Camera*

Framing Cameras use reflectance of visible EMR from the surface of the asteroids to

- measure the surface albedo
- map surface topography

*GRaND*

Cosmic rays strike the asteroids' surface causing formation of fast, thermal, and epithermal neutrons. Decay of fast neutrons release gamma rays.

GRaND measures gamma radiation from radioactive elements in the protoplanet's surface and the gamma radiation resulting from fast, epithermal, and thermal neutrons interacting with sensors to

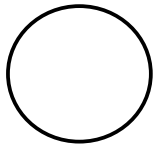
- measure the concentration of surface elements

As the Dawn Spacecraft orbits the asteroid, changes in mass concentration cause changes in the spacecraft's line of sight velocity, which are reflected in changes in radio wave frequencies. Red and blue Doppler shifts (frequency changes) are detected by the Radio Communications System and analyzed to

- form a mass concentration map of the protoplanet's surface.

When information from the three Dawn instruments and the Radio Communications System are combined, they will increase our knowledge of the asteroids' surface minerals and the spatial distribution of those minerals.

**Examples of shape and color-coding for classification of terms and objects**

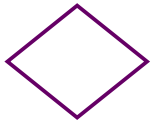


Black Circle-Dawn Instrumentation Payload

Black rectangle- Dawn Spacecraft Instrumentation

Gray rectangle - Radio Communications System

Red rounded rectangle – Range of EMR interacting with instrumentation

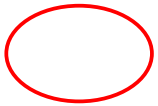


Plum diamond-Neutrons released by Cosmic radiation interacting with instrumentation to form Gamma Ray EMR

Blue trapezoid-Result of instrument analysis of matter-energy interactions

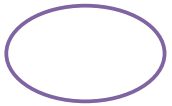
Green rounded rectangle-Dawn Scientific Objective accomplished Na

Plum Energy Bolt-Cosmic Ray



Red solid line oval –Red Doppler Shift

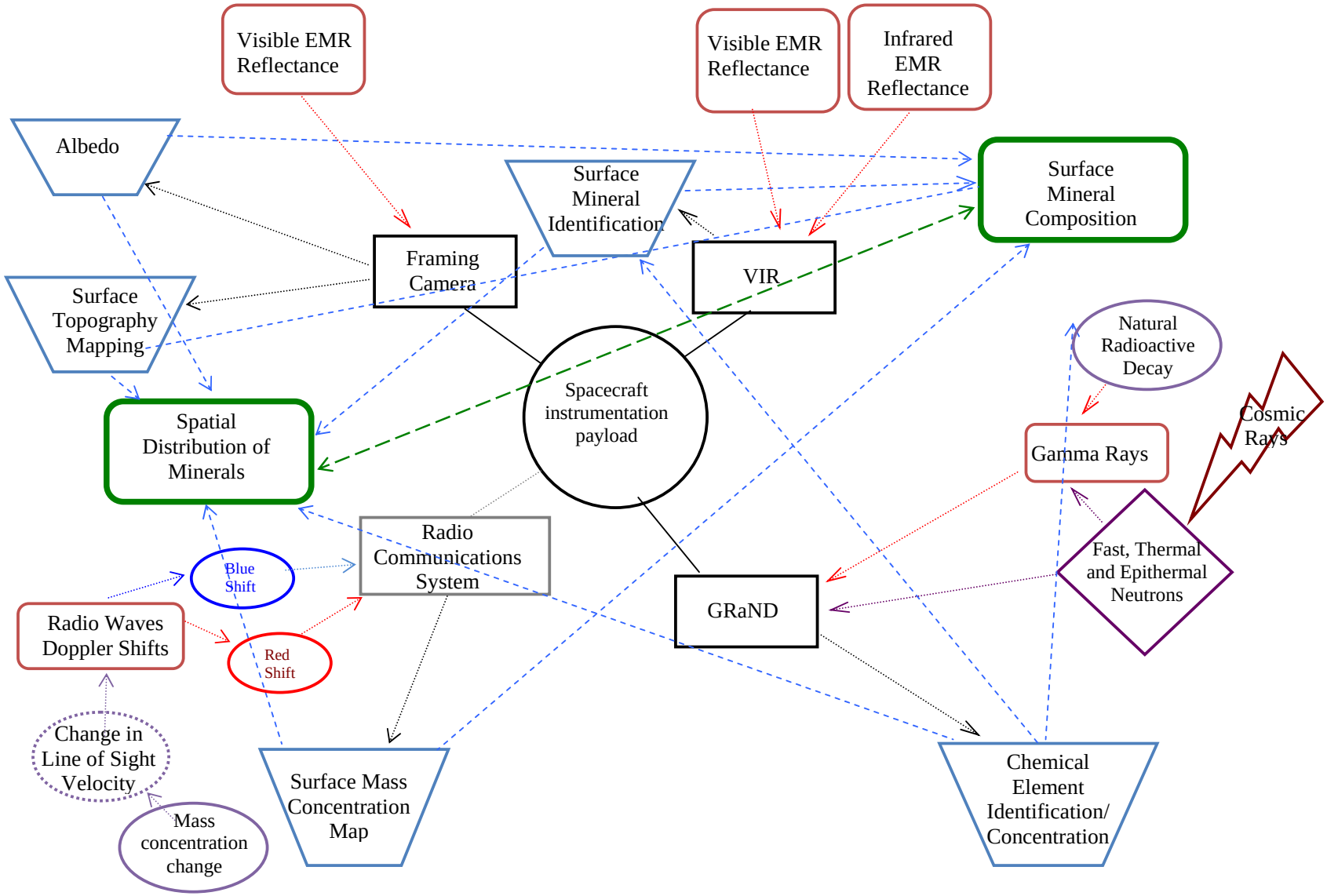
Blue solid line oval-Blue Doppler Shift



Violet solid line oval-Natural elemental properties

Violet dashed line oval-results of natural elemental properties

## Sample Concept Map: Origins of EMR Matter-Energy Interactions and Relationships



**Terms to include in the *Science and Technology of EMR Matter-Energy Interactions and Relationships Concept Map***

Albedo
BGO Sensor
    Gamma Rays from Volatile/ Stable Elements
Changes in Line of Sight Velocity
Charge coupled device (CCD)
Chemical element identification/concentration
Cosmic Rays
CZT Sensor
    Gamma Rays from Radioactive Elements
Data processing unit (DPU)
Framing Camera
Filter wheel
4-lens optical system
Gamma Rays
GRaND
High Altitude Mapping Orbital (HAMO) Optical mapping
Infrared Reflectance
Low Altitude Mapping Orbital (LAMO) Optical mapping
Mass concentration change
Navigation function
Neutrons
    Fast
    Thermal
    Epithermal
Offner spectrometer
    Diffraction grating
        Visible EMR
        Infrared EMR
    Infrared Focal Plane Array (IRFPA)
Radio Communications System
Radio Waves Doppler Shifts
    Red shift
    Blue shift
Shafer telescope
    Aluminum and beryllium mirrors
Spacecraft instrumentation payload
Spatial Distribution of Minerals
Surface Mass Concentration Map
Surface Mineral Composition
Surface Topography Mapping
Surface Mineral Identification
VIR
Visible EMR Reflectance

## Narrative Outline Example

Example of a narrative outline that indicates the grouping, interactions, and relationships shown in the map are included in the following page and how this map explains how these interactions will help meet the objectives of the Dawn Mission

*VIR-Visible and Infrared Imaging Spectrometer*

VIR uses visible and infrared reflectance from the surface of the asteroids to

- determine the mineral composition of surface materials and
- their spatial distribution

Visible and infrared EMR reflected from the asteroids' surface enters VIR's Shafer telescope, where it is reflected and focused by aluminum and beryllium mirrors and enters VIR's Offner spectrometer. The diffraction grating in the spectrometer divides the EMR into visible and infrared wavelengths. A CCD (charge-coupled device) detects and images visible radiation and an IRFPA (Infrared Focal Plane Array} detects and images the infrared EMR. The spacecraft's Data Processing Unit (DPU) produces spectroscopic graphs from these data.

*Framing Camera*

Framing Cameras use reflectance of visible EMR from the surface of the asteroids to

- measure the surface albedo and
- map surface topography

The Dawn Spacecraft will map the surface of the asteroids from both High Altitude Mapping Orbit (HAMO) and Low Altitute Mapping Orbit (LAMO). The visible EMR reflected from the asteroids' surfaces will be focused by a four-lens refractive optical system. An eight-position filter wheel will provide a spectral analysis of the asteroids' surfaces. A charge-coupled device (CCD) and a data processing unit (DPU) will convert this data into surface images.

*GRaND*

GRaND has two gamma ray spectrometers which will detect gamma rays escaping from the asteroids' surfaces. GRaND's CZT sensor detects gamma rays from naturally radioactive elements like potassium, thorium, and uranium.

Cosmic rays strike the asteroids' surface causing formation of fast, thermal, and epithermal neutrons. Radioactive decay of some fast neutrons release gamma rays. Other neutrons leak from the asteroids' surface and interact with GRaND scintilators to produce gamma rays. GRaND's BGO sensor is sensitive to these gamma rays from stable and volatile elements.

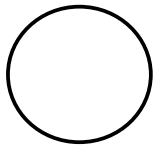
- GRaND uses data from both the CZT and BGO sensors to identify and measure concentrations of surface elements.

As the Dawn Spacecraft orbits the asteroids, changes in mass concentration cause changes in the spacecraft's line of sight velocity, which are reflected in changes in radio wave frequencies. Red and blue Doppler shifts (frequency changes) are detected by the Radio Communications System and analyzed to

- form a mass concentration map of the asteroids' surface.

When information from the three Dawn instruments and the Radio Communications System are combined, they will increase our knowledge of the asteroids' surface minerals and the spatial distribution of those minerals

**Examples of shape and color-coding for classification of terms and objects**

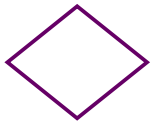


Black Circle-Dawn Instrumentation Payload

Black rectangle- Dawn Spacecraft Instrumentation

Gray rectangle - Radio Communications System

Red rounded rectangle – Range of EMR interacting with instrumentation

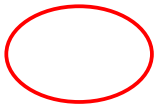


Plum diamond-Neutrons released by Cosmic radiation interacting with instrumentation to form Gamma Ray EMR

Blue trapezoid-Result of instrument analysis of matter-energy interactions

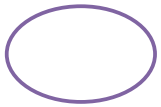
Green rounded rectangle-Dawn Scientific Objective accomplished

Plum Energy Bolt-Cosmic Ray



Red solid line oval –Red Doppler Shift

Blue solid line oval-Blue Doppler Shift

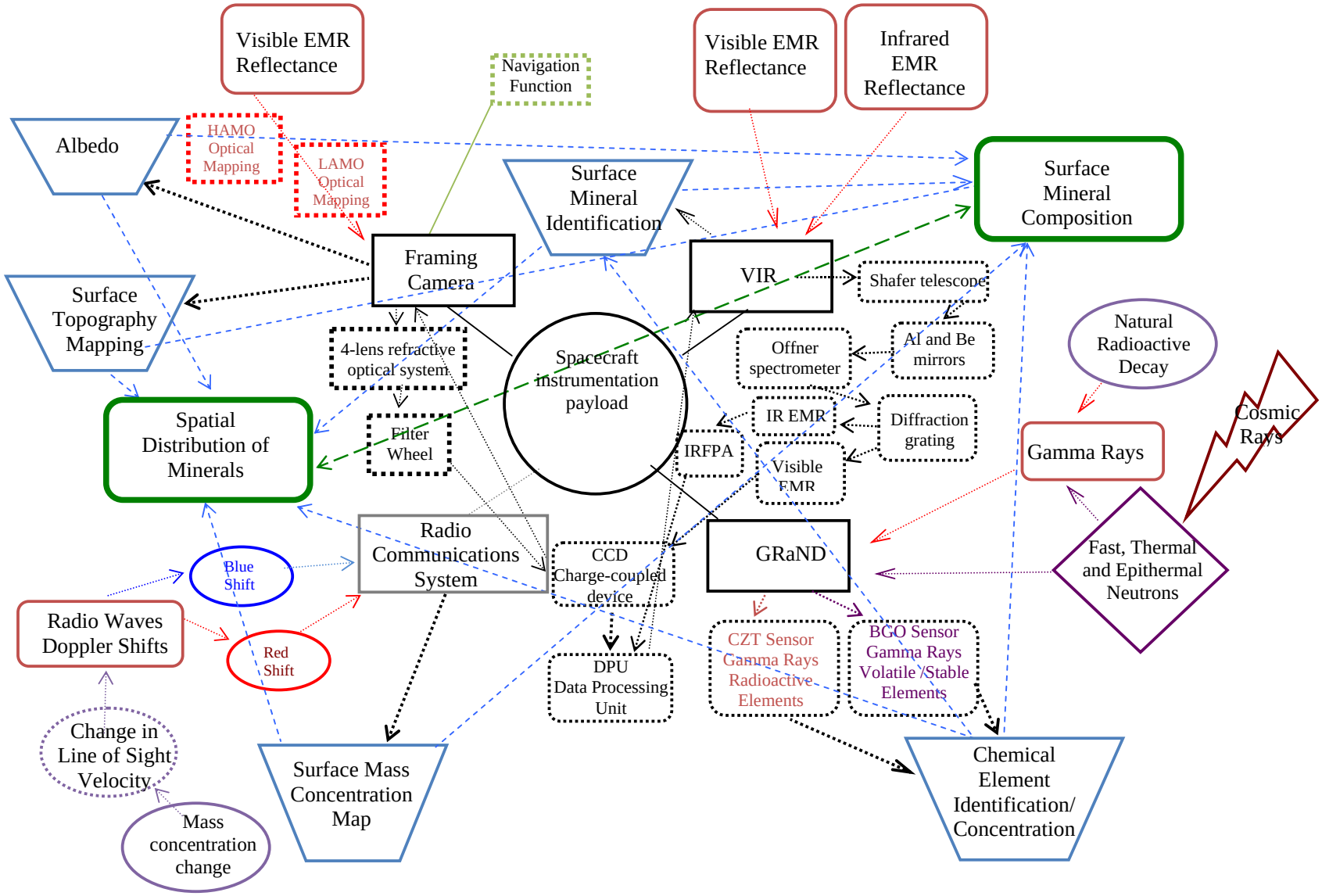


Violet solid line oval-Natural elemental properties

Violet dashed line oval-results of natural elemental properties

Black dashed line rounded rectangle-internal instrument technology

Red dashed rectangle-orbital altitude of spacecraft

Gray-green dashed rectangle – external function technology

## Sample Concept Map: Science and Technology of EMR Matter-Energy Interactions and Relationships