Design Laboratory Assignment
A Radiator in Space

ASEN 3113: Thermodynamics and Heat Transfer

Assigned: 10/23/2019

All Group Presentation Slides due 5:00 pm on 12/4

Group Presentations: start at 2:30 pm on 12/5 (Th Groups), at 10:30AM on 12/6 (Fri Groups)

1.0 Background and Introduction

1.1 GOES-R

The Geostationary Operational Environmental Satellite (GOES) constellation provides continuous monitoring of meteorological conditions in the Western hemisphere. Operated by the National Oceanic and Atmospheric Administration (NOAA), the two active GOES spacecraft also monitor the space environment, receive and transmit search-and-rescue data, and relay ground-based environmental platform data.

A major upgrade to this system, known as GOES-R, was launched on November 19th, 2016. GOES-R is a major step forward in the fields of weather, atmosphere, climate, solar observation, and ocean monitoring. Its launch marked the first technological advance in GOES instrumentation since 1994. The combined instrument downlink data rate increased by a factor of 60, and the number of environmental product types increased by a factor of 4. The amount of environmental data being rebroadcast to users throughout the hemisphere increased by an order of magnitude.

Figure 1 **Earth surface area covered by two GOES spacecraft.**

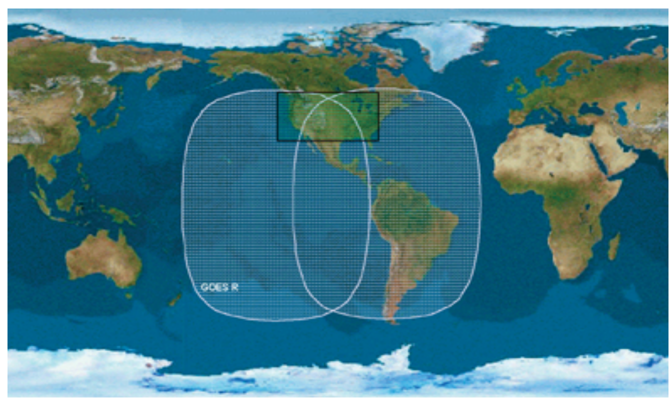
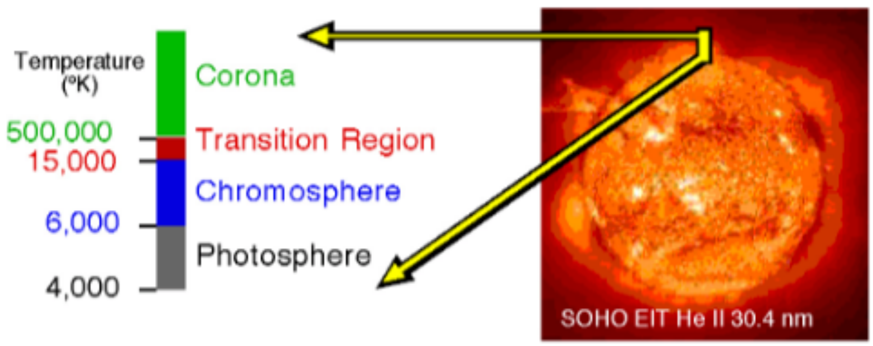


Figure 2 **Picture of the GOES-R spacecraft.**

1.2 Monitoring the Solar EUV Irradiance from GOES-R

The sun's extreme ultraviolet (EUV) radiation consists of emissions from the solar chromosphere, transition region, and corona at wavelengths less than 127 nanometers (λ<127 nm). EUV radiation accounts for < 0.01% of the Total Solar Irradiance (TSI), from which >99% originates in the photosphere. The Sun's EUV spectra can have variations from a factor of 2 up to a factor of 100 (wavelength dependent), whereas TSI variations are typically only 0.1%. EUV is completely absorbed in Earth's atmosphere, and EUV photons are energetic enough to ionize the atmosphere (this creates the ionosphere). The highly variable solar irradiance in the 0.1 to 200 nm range is absorbed in the Earth's mesosphere and thermosphere causing ionization, dissociation, and heating. These lead to photochemistry and dynamics. Variability in the solar irradiance leads to variability in the Earth's atmosphere, which impacts communications, satellite drag, navigation, etc. An EUV instrument has been designed to be on board GOES-R to monitor the solar EUV variation.

Figure 3 EUV radiation emission sources



1.3 Assignment: Design a Radiator

The EUV instrument must maintain a high level of data accuracy over the 10 year mission lifetime. The stability of the instrument's optical bench is imperative to maintaining this accuracy. The optical bench is sensitive to thermal distortions, so strict operational temperature requirements must be met during science data acquisition. The instrument will be passively cooled using a radiator, and will use heater power to maintain the thermal requirements as the space environment varies.

As a group, your assignment is to perform a design analysis of an instrument radiator. You will report your findings in a 10-minute group presentation, upon which your group grade will be based. You should determine the following design aspects for the instrument radiator:

- Surface treatment of the radiator (what kind of surface coatings, with flight heritage, are needed to achieve the desirable absorptivity and emissivity)
- Required radiator area (in units of m^2)
- Operational heater power as a function of time over one orbit (around the Earth) for solstices and equinox
- Survival heater power as a function of time over one orbit (around the Earth) for solstices and equinox

Your design requirements are as follows:

1.3.1 Power. The instrument shall draw 20W of power while operating, which is dissipated as heat. You can assume that any needed power is available from the spacecraft, and the instrument sensor is connected to the radiator and in thermal equillium with the radiator.

1.3.2 Orbit. The spacecraft on which the instrument resides shall be located in a geostationary orbit. Due to the orbit altitude, Earth infrared (IR) and albedo loading can be ignored.

1.3.3 Orientation. The spacecraft shall have one surface continually nadir pointing. The radiator shall be rigidly mounted on the trailing surface, opposite to the ram direction or velocity vector of the spacecraft.

1.3.4 Operational Thermal Requirements. The instrument shall be maintained between 20°C and 30°C in order to acquire science data accurately (safety margin is already included here, no need to add any extra margin).

1.3.5 Survival Thermal Requirements. When the instrument is powered off, the instrument shall be maintained above -40°C to prevent any damage from occurring (safety margin is already included here, no need to add any extra margin).

1.3.6 Spacecraft IR Backload. The infrared (IR) heat load from the rest of spacecraft to the radiator, at its given location, shall vary with the orbital environment. Use the following IR backload values (during the equinoxes, the IR Backload is just the average of the values at Winter and Summer Solstices, except during eclipse):

Winter Solstice	88 W/m^2
Summer Solstice	63 W/m^2
Eclipse	11 W/m^2

2.0 Learning Goals

In this Design Lab, you have the opportunity to achieve the following learning goals:

1. Learn about the requirements of spacecraft thermal control.
2. Integrate your knowledge of heat transfer into a practical design analysis.
3. Use MATLAB, Excel, or other programs for plotting engineering calculations and for performing numerical integration.
4. Learn research skills, both in the Library and on the Web.
5. Further develop your teamwork and presentation skills.

3.0 Required Deliverables

3.1 Group Presentations

Your group will prepare an **8-minute presentation** reporting the results of your design investigation. This report must present how each requirement is met by your design *in a quantitative manner supported by analysis and research*. It must also provide some rationale for your choices. Your group will turn in your .pdf or .pptx file before your presentation.

3.2 Individual Peer Reviews

Each person must submit confidential peer reviews of their teammates. Refer to the course schedule for due date and time. Consider their presence, punctuality, contributions to discussion, and overall work in general. This evaluation will be treated confidentially and not be shown to your lab partners.

Suggest Study Questions/Issues

The following questions are offered to help you clarify the issues involved in this assignment.

1. Formulate a “homework problem” that computes the minimum required radiator area.
2. Write a MATLAB or Excel function that computes and plots the heater power and the radiator temperature as a function of time during a one-day orbit for different seasons. At first, use assumed values for the parameters that you need to research. Then, as your research progresses, insert those values into your code. The final values for some parameters will be given near the end.

4.0 Suggested Activities

You are free to plan your schedule as you wish. However, we offer the following set of weekly objectives to help guide your development. Every group may adapt their own variation of these suggestions. You are expected to attend each laboratory session. Your group will be expected to present briefings to Prof. Li on the week of 11/11 and 11/18.

4.1 <u>Week 1</u>: Organize your groups. Brainstorm ideas. Draw pictures of the problem to make sure you understand the parameters of the assignment. Try to distill the problem into a few equations. Formulate at least the “homework problem” for the design.

4.2 <u>Week 2:</u> Research needed information while others write the code, and test the code with available information.

4.3 <u>Week 3</u>: Begin to draft your presentation. Identify missing pieces that require further work.

4.4 <u>Week 4</u>: Finish your presentations. Revise, revise, and revise; practice, practice, and practice!