

Work Packages for Teams Supporting *Live From Earth and Mars—Science, Technology, Education, Partnerships* (LFEM-STEP)

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Abstract

Implementation of LFEM-STEP at the elementary and middle schools presumes there is access to certain equipment in quantity sufficient to support the number of students involved. To make the program cost-effective and *self-replicating*, LFEM-STEP will be supported by teams of students, faculty, and volunteers from other levels in the educational system and from the community. Students from high school, college, and graduate school levels may be involved in such teams.

This document defines potential activities to which these teams may commit, and how team participation may support educational goals of the programs from which the students are drawn. The term *work packages* is used to define subdivisions of the overall support effort needed to implement LFEM-STEP.

Taken as a whole, the LFEM-STEP support infrastructure discussed here has the characteristics of an engineering project. As such, it uses a work breakdown structure (WBS) that covers a continuum of design, fabrication, and support elements that draw from a diverse pool of skills. Work packages are elements of the WBS. By keying work packages to educational goals, the LFEM-STEP support activity provides a wide range of opportunity for students at various levels of engineering and technology training to gain practical experience in their own fields.

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1 Introduction

1.1 Live From Earth and Mars—Science, Technology, Education, Partnerships (LFEM-STEP)

LFEM-STEP¹ is an outreach program of science teaching for students in the K–12 grades. The following briefly introduces the elements of LFEM-STEP without attempting to be definitive.

1.1.1 Temperature of Earth and Mars (TEM)

This module is composed of K–12 science experiments that expose students to temperature-energy relationships, while using scientific research methods. Temperature is often confused with heat loss or gain (i.e. energy exchange). As students progress, experiments help improve their understanding of the difference between temperature and energy, and temperature-energy relationships. By comparing local time and space temperature variations, students develop a realization of the difficulty of obtaining representative temperature measurements, and of methods that improve such estimates. Statistical concepts such as averages and variability are introduced in primary schools, and explored in greater depth in secondary and high schools to help understand the characterization of global temperature, and its changes.

1.1.2 School Research Weather Stations

LFEM-STEP is supported by collaborative installation of School Research Weather Stations at grade K–12 schools. Students explore the atmospheric conditions of their own school environment by using these fast and sensitive weather stations. The on-site measurement of school atmospheric conditions provides a scientific springboard that piques student interest in complex concepts such as energy exchange and average versus extreme events. Inter-comparisons between LFEM-STEP schools in different cities worldwide allows students to interact and communicate with one another, and encourages cooperation beginning at a young age. The research quality weather stations provide an observational context for the TEM experiments. By means of the world wide web (WWW), they integrate observations in real time with a weather database maintained at the University of Washington (UW) that supports the TEM modules described in section 1.1.1.

1.1.3 NetLander Mars Mission

The NetLander Mission to Mars is the third component of the LFEM-STEP program. The mission includes several scientific experiments with LFEM-STEP interactively using mission results. NetLander consists of a network of four landers at different locations on the Martian surface that will make coordinated observations, including atmospheric measurements beginning in 2008. NetLander activities explicitly provide for LFEM-STEP K–12 and university students to participate. Among their activities, students at participating LFEM-STEP schools will compare real-time Mars meteorological observations with the atmospheric conditions at their own schools and throughout planet Earth via the Internet, using the TEM WWW infrastructure (section 1.1.1).

1.2 LFEM-STEP Infrastructure Requirements

Initial implementation of LFEM-STEP focuses on TEM and School Research Weather Stations. These elements require an equipment and support infrastructure in the schools sufficient to allow

¹http://www.atmos.washington.edu/~mars/exec_head_v2-2.html

the hands-on interaction of students with the tools they need to explore their environment.

A critical requirement of all LFEM-STEP infrastructure development activities is that they teach students how to develop, execute, and document their goals, objectives, plans, and products. A major goal is to make LFEM-STEP a self-replicating structure, giving its participants the ability to train others in turn.

1.2.1 TEM Requirements

The principal focus of TEM is individual measurements made by individual students or pairs of students. They require small handheld temperature sensors that can be used in the classroom or outdoors that provide the means of accurately measuring temperature in the environment. Development, fabrication, calibration, and maintenance of the sensors must be addressed by the LFEM-STEP support infrastructure. The approach will be based on prototype hardware already developed and tested. The Electrical Engineering (EE) Department at UW intends to participate in design improvement through student collaboration.

1.2.2 School Research Weather Stations Requirements

In contrast to the TEM sensors, the school research weather stations represent a central resource in each participating school that supports TEM as well as other teaching modules. Design, development, fabrication, calibration, test, maintenance, ongoing operational issues must all be addressed. Weather stations will be assembled from research quality components. They will include facilities for internet distribution of data.

1.3 Approach to Meeting LFEM-STEP Infrastructure Requirements

LFEM-STEP infrastructure requirements will be addressed by teams composed of more advanced students (i.e. high school and college level), their teachers, and volunteers from the community. Because the LFEM-STEP infrastructure involves a broad range of engineering and technology disciplines, work will be broken down to allow the support teams to effectively bring their skills to bear where needed most.

1.3.1 Work Packages

As is typical in engineering projects, tasks are categorized according to a work breakdown structure (WBS) composed of elements called *work packages*. Teams will commit to one or more work packages, assuming responsibility for delivery of data, hardware, and/or software systems to teams working on related work packages. Teams will, in turn, receive data, hardware, and/or software systems produced by teams working other work packages. This process has proven in the engineering industry to provide an effective means of subdividing work while allowing specialists to focus their work independently on a relatively narrow task assignment.

Each work package (an element of the WBS) will consist of a statement of goals, a statement describing the activity to be carried out, a definition of package deliverables, and a schedule.

1.3.2 Curriculum Elements

In addition to addressing tasks of an engineering nature, the LFEM-STEP infrastructure support teams will function within the context of an educational environment. Each work package will be keyed to curriculum elements. These curriculum elements will be matched to the curriculum

in place where the students are learning. This approach is intended to maximize benefit to the student team members by matching team activities to their educational goals. It also benefits them through exposure to best practices used by top experts in the various fields. People from Boeing, UW, MIT, Viking program, etc. will be involved.

1.4 Purpose of This Document

This document introduces the concept of using support teams to create and maintain an infrastructure for LFEM-STEP. It gives an overview of an approach to organizing the teams to accomplish the tasks necessary to produce the tools needed for student learning via the LFEM-STEP modules.

This document describes the engineering project management tool of the WBS and its work packages. It provides educators considering participation in an LFEM-STEP team an introduction to the process to be used and gives an overview of the work packages themselves and how they relate to educational objectives.

2 Temperature of Earth and Mars Sensors

LFEM-STEP's TEM modules are based on student exploration of their environment using *temperature sensors*. They also use the sensors to learn about sensor characteristics and sensor limitations. The sensors are based on technology used by the Viking landers to measure the Martian temperature environment. They are small, low-cost, handheld units designed for use by individual students or pairs of students.

2.1 Functional Requirements of the TEM Sensors

In summary, the sensor modules are battery powered, hand-held in size, weigh a few ounces, and provide a means of interchanging thermocouple elements having differing thermocouple wire gauge (i.e. differing wire diameter to investigate accuracy/robustness tradeoffs). The modules are provided with a display of measured temperature on an LCD display. The temperature is sampled at least once per second.

2.2 Present Status of TEM Sensor Design

A design of a prototype TEM sensor module has been developed. Several dozen sensor modules based on this design were fabricated and used in pilot application of TEM education modules to date.²

The existing sensor modules are based on the Analog Devices AD595 thermocouple system chip. The chip is mounted on a small circuit board and housed in a metal box that carries a standard thermocouple connector and a pair of output connectors. Power is provided by a 9-volt battery mounted outside the box. The output signal is a direct current voltage equal to 1/10 the Celsius temperature. Temperature display is accomplished by reading this output voltage on a low-cost digital voltmeter (DVM) obtained on the surplus market.

While workable for the piloting phase of LFEM-STEP educational module development, the present sensors have drawbacks that must be addressed by re-design. The complete sensor module consists of two elements—the thermocouple system box and the DVM. This configuration forced students to use both hands to handle the complete sensor module, requiring a partner to record the data. The interconnection wires between the elements proved to be a source of failure as connections

²<http://www-k12.atmos.washington.edu/k12-dev/temperature2/>

at either end were not positive. Finally, the DVM units were a “one-time buying opportunity” that might not be replicated.

Improvements to the sensor display and storage devices will be an activity of the UW EE Department student collaboration.

2.3 TEM Sensor Module Work Breakdown Structure

Re-design of the TEM sensor modules will be approached by applying the engineering project management discipline. Tasks to be assigned to the participating teams will be drawn from elements of the WBS. The following elements make up the tentative WBS:

- Define Requirements
- Preliminary Design
- Preliminary Design Review (PDR)
- Detailed Design
- Critical Design Review (CDR)
- Fabrication and Test

Individual items in the WBS constitute work packages to be assigned to individual teams supporting development of the TEM sensor modules.

Details of the individual work packages are given in Figs. 1 and 2. These include a statement of goals and the activity description. Finally, a tentative list of related curriculum elements is provided for each work package.

3 School Research Weather Stations

Some LFEM-STEP student activities are based on weather observations made by School Research Weather Stations. These installations are installed in participating schools and provide research grade observations, accessible to the students via computer networks in the school and via the internet. Besides making observations of the weather environment of their own school, students can share data between school weather stations via the internet. Weather data from the stations is transmitted via the internet to UW for integration into the WWW real-time storage and display infrastructure that supports TEM. This system has been operational for more than five years.³

3.1 Functional Requirements of the School Research Weather Stations

The school research weather station installations measure a variety of meteorological parameters. These are measured at *high resolution*, meaning observations are continuously recorded every 1–5 seconds. Parameters include the following:

- Temperature
- Wind speed and direction
- precipitation

³http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html

- Pressure
- Humidity
- Solar radiation

3.2 Present Status of School Research Weather Stations

Physical realization of weather stations installed to date has been based on commercial, research grade sensor elements. Data acquisition has been accomplished using Campbell data logger modules— instruments of extremely high reliability that acquire data, convert it to scientific units, provide statistical analysis, and transfer it to Intel computers using Linux operating system software. The computers are connected to the internet via the school’s network. Data are interchanged between weather stations and the UW central site using the Unidata Internet Data Distribution system. Unidata provides a superior means of exchange of digital information among sites. Its high reliability supports the required unattended operation of the School Research Weather Stations.⁴

Initial School Research Weather Station installations were developed by F. Weller, an engineer having more than thirty years experience in design, assembly, test, and installation of sensor systems. Future installation design will benefit positively by incorporation of the design heritage of the systems he developed.

3.3 School Research Weather Stations Work Breakdown Structure

In contrast to the TEM sensor module status, the school research weather station system design is relatively mature and does not require a re-design effort. Instead future efforts will focus on standardizing the configuration and providing an efficient mechanism for setting up additional stations. In addition, ongoing efforts must be directed toward maintenance and operation of the weather stations and management of data collected and distributed.

The following elements make up the tentative WBS for school research weather stations:

1. Provide weather station hardware
2. Weather station installation and maintenance
3. Weather station information technology infrastructure
4. Data collection and distribution
5. Monitor sensor performance

As with the TEM sensor module WBS, individual items in the WBS constitute work packages to be assigned to individual teams supporting school research weather stations.

Details of the individual work packages are given in Fig. 3. These include a statement of goals, the activity description, and a tentative list of related curriculum elements for each work package.

4 Curriculum Elements

To maximize benefit to students involved in LFEM-STEP infrastructure support, work packages must be keyed to elements of the student curriculum. Student activities within the various work

⁴<http://www.unidata.ucar.edu/packages/netcdf/>

packages may range from vocational-technical activities such as electronics or mechanical assembly to design and analysis tasks in the areas of electronics and information technology.

A list of curriculum elements likely to match one or more of the work packages has been generated. This should be considered tentative because the range of educational institutions to be involved in LFEM-STEP infrastructure support is not yet known. Tentative curriculum elements are the following:

- Electronics technology
- Mechanical technology
- Pre-engineering
- Information technology
- Construction
- Network technology
- K-12 education
- Project management
- Documentation

These curriculum elements have been keyed to the WBS work packages given in Figs. 1, 2, and 3.

The list of curriculum elements should expand as educators become involved and review the work packages. This collaborative approach is expected to benefit both the project and the students' educational opportunities by achieving the best match between project activities and student needs.

| Work Package | Goals | Activity | Curriculum Element |
|---------------------------------|---|---|---|
| Define Requirements | Specify functional, package, cost, and interface requirements | In conjunction with teaching module development and definition process, identify parameters to be measured (e.g. temperature, time, other physical parameters), package size, unit cost goal, and define interface to data logging hardware. | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Pre-Engineering • Information Technology • K-12 Education • Documentation |
| Preliminary Design | Identify and analyze candidate design approaches | Based on requirements and prior development experience, select candidate circuit elements (e.g. AD595 thermocouple system); plan integration and packaging; analyze performance in terms of requirements; prototype promising approaches. Perform preliminary down select of best design options. | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Construction • Information Technology |
| Preliminary Design Review (PDR) | Review selected preliminary design options | Review results of the preliminary design process for conformance with requirements; provide feedback to design team; if appropriate authorize specific approach for detailed design and development. | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Information Technology • Project Management |

Table 1: Work packages available for *TEM Sensor Module* collaborating high schools and colleges. (Part 1: Requirements Definition through Preliminary Design Review.)

| Work Package | Goals | Activity | Curriculum Element |
|------------------------------|--|--|---|
| Detailed Design | Complete detailed design in preparation for fabrication | Update preliminary design based on input from PDR. Proceed with detailed design, prototype fabrication and test. Detailed design to include documentation of estimated cost, parts list, operation and test specifications, and interface documentation; drawing release for circuit boards, mechanical elements and case, sensor configuration, etc.. | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Information Technology • Documentation |
| Critical Design Review (CDR) | Review finalized design for release to fabrication | Critically review final design for conformity to requirements and suitability for fabrication; approve release to fabrication. | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Information Technology • Project Management |
| Fabrication and Test | Establish production capability for fabrication of sensor module and interface hardware elements | For CDR-approved design establish fabrication infrastructure: procure material; fabricate subassemblies; assemble; calibrate and test. | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Information Technology |
| Process Documentation | Document process and procedures required for replication | Produce a design summary document that embodies the details of all project phases with the goal of supporting self replication —future implementation by others. | <ul style="list-style-type: none"> • Project Management • Documentation |

Table 2: Work packages available for *TEM Sensor Module* collaborating high schools and colleges. (Part 2: Detailed Design through Process Documentation.)

| Work Package | Goals | Activity | Curriculum Element |
|---|--|--|---|
| Provide Weather Station Hardware | Design, assemble, calibrate, integrate, and test weather station hardware | Build and integrate electronic, computer, and sensor modules, participating in system design and integration planning in conjunction with supporters and program management | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Pre-Engineering • Information Technology • Documentation • Project Management |
| Weather Station Installation and Maintenance | Install weather stations at new locations and maintain existing installations | Carry out placement of weather stations at schools joining LFEM-STEP and maintain existing installations in the field | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Construction • Information Technology |
| Weather Station Information Technology Infrastructure | Install computers, networks, and software for operation of the weather station network | Configure computers; set up operating system, application, and network software; configure networks; validate IT functions for new school weather station installations | <ul style="list-style-type: none"> • Information Technology • Network Technology |
| Data Collection and Distribution | Support data collection and manage distribution | Monitor collection of data from weather stations on central server. Troubleshoot and repair school site computer/network system outages | <ul style="list-style-type: none"> • Information Technology • Network Technology |
| Monitor Sensor Performance | Monitor sensor performance to validate and continuously improve weather station accuracy and performance | Perform experiments related to sensor design, placement, and operation in the context of field application and under the full range of encountered meteorological conditions to provide feedback to the design team for continuous improvement | <ul style="list-style-type: none"> • Electronics Technology • Mechanical Technology • Pre-Engineering • Information Technology |

Table 3: Work packages available for *School Research Weather Station* collaborating high schools and colleges