1. Introduction

Historical Scientific Perspective

Of all of the characteristics which distinguish humans from other living species, the ability to study and to understand the nature of matter is undoubtedly the most unique. Centuries ago the early Greeks theorized that different types of matter were composed of tiny indivisible particles called atoms with each type having a unique character. However, mankind needed to wait more than two millennia before its own experimental evidence proved the validity of that hypothesis.

With the discovery of the electron in the late 19^{th} century followed by the discovery in the early 20^{th} century that atoms had their mass concentrated in a very tiny core about which the electrons moved, a quantitative understanding of atomic structure began to emerge. The interactions of atomic electrons with each other and with light particles called photons was shown to be responsible for almost all physical phenomena which humans experienced. For example, electricity consists of the movement of electrons in conducting materials under the influence of an electric field, semi-conductors function through electron exchange between surfaces, and radio waves are emitted by electrons which undergo accelerations. The phenomena of electrical interactions is well understood and is summarized as "Electromagnetism", a theory first unified by Maxwell in the 1870's.

During most of the 20^{th} century, intensive studies were made into the substructure of atoms and its core, called the nucleus. This led to discoveries of many new subatomic particles such as neutrons, mesons, leptons, quarks, and neutrinos and to the nature of their properties and interactions which in those instances were more dominant than the electromagnetic interactions. These discoveries were made possible through advancements in the technology of particle accelerators which propel electrons and protons to energies many orders of magnitude greater than their values within stable atoms. One of these devices was the electron synchrotron and was especially important in providing the capability of determining the structure of the atomic nucleus.

These devices had one rather distressing feature which was that the circulating electrons would radiate more and more of their energy into electromagnetic radiation as their energies increased subsequently limiting the energy to which electrons could be raised.

This radiation emitted by electrons confined to circular orbits by magnetic fields began to be referred to as "synchrotron radiation", although the characteristic that accelerated charged particles radiate energy is a general consequence of electromagnetic theory. The spectrum of the radiation, its intensity, and direction relative to the direction of the electron are all predictable. For a physical device such as a synchrotron of several GeV using 1 Tesla field strength magnets, the spectrum is predominantly in the ultraviolet and soft X-ray portion of the electromagnetic spectrum. The power of the emitted radiation increases as the fourth power of the electron's energy (E^4) and the direction of the radiation is heavily concentrated in the direction of the radiating electron.

During the period of intense development of very high energy circular electron accelerators, (synchrotrons), in the later part of the 20^{th} century, it began to become apparent that the intensity of this synchrotron radiation emitted by high energy electrons during their traversals in circular orbits was much higher than the intensity from more conventional devices such as X-ray tubes. This feature attracted materials scientists, biologists, and others to consider instead using high energy physics facilities for conducting their studies on a "parasitic" basis whenever these facilities were operative. By the 1980's, demand for and usage of synchrotron radiation had mushroomed to the point where new facilities were built as "dedicated" facilities, specifically for the purpose of producing synchrotron radiation. Thus, a whole new industry was spawned from radiation deemed to be a "waste product" by researchers engaged in the studies into sub-atomic physics.

Current Situation in Electron Storage Rings

The advancement from the early "parasitic" mode of operation to today's "state of the art" dedicated facilities has been a rapid evolution and has culminated in a revolution in many diverse areas in addition to the ones mentioned. They include chemistry, pharmacology, geology, environmental science, micro technology, medicine, and many other related fields.

With the exponential type growth in the usage of synchrotron radiation, the number built in the past twenty years has increased to over 40 facilities throughout the world, concentrated principally in the U.S., Europe, and Japan. Total investment in these facilities now is in the billions of dollars. More recent and notable efforts to develop such facilities are ongoing in the United Kingdom, France, Canada, and Australia together with upgrades of existing facilities in the U.S.

A number of important changes in the features of the facilities, such as capabilities, size, mode of operation and costs have occurred during this period. Essentially all new facilities are now dedicated and operate with beam available on a continuous basis, resulting from operating the accelerator as a storage ring in which electrons are contained for long periods of hours or even days, emitting synchrotron radiation at power levels of several hundred kilowatts. To achieve this type of performance, a great deal more care and sophistication needs to be taken than for synchrotrons where electrons might only need to be contained for fractions of a second. Much higher tolerances in component fabrication need to be maintained and much tighter monitoring and adjustments of electron trajectories within the storage ring are required.

In response to user demands for more flux (intensity of photon beam) and emittance (brightness), new third generation facilities incorporate a number of new features including higher circulating currents of electrons of several hundred milliamperes, higher electron energies of a few to several GeV, special devices such as wigglers or undulators inserted into the magnetic structure of the storage ring, and well instrumented photon beam lines with monochromatic, highly collimated and precise properties.

Because synchrotron radiation is emitted at all locations where electrons are magnetically deflected from a straight line, radiation is emitted at many locations around the storage ring. For a storage ring such as CANDLE, which contains 32 dipoles, approximately 80 photon beam lines may be achieved. Each of these beam lines could conceivably be split into a few experimental stations resulting in excess of 100 or more stations to conduct the research. Cost is the controlling factor of instrumenting the number of beam lines since each line costs between 0.5 and 2.0 million dollars.

Because of the nature of the experiments to be conducted and the extremely high fluxes and brightness of the photon beams, the time for conducting an experiment or exposure can frequently be measured in minutes rather than days, thereby allowing the usage of a single beam line by many groups of scientists during a year. Experience at other synchrotron radiation facilities such as SPEAR 2 at SLAC indicates that thousands of user groups can

be accommodated on an annual basis. A broad range of scientific specialties can be simultaneously served.
In summary, a third generation synchrotron radiation light source contains several desirable features, as listed below, which make it an attractive candidate for investment by a country or region desirous of strengthening its scientific programs and potential:

- Large numbers of scientists from a number of diverse fields, basic and applied, are likely to utilize the facility.
- New state of the art facilities allow researchers to extend their investigations with greater accuracy and sensitivity than is presently achievable.
- The work to be conducted is likely to be frontier and to have a greater likelihood of leading to new discoveries which may have major benefits to society.
- Usage of beam lines for medical treatment and diagnosis provides a major resource to maintain and improve the health of the overall population.
- Usage by the pharmaceutical and microtechnology industries in the commercial development of new drugs and micro devices enhances the economic well being of the nation.

The CANDLE Proposal

The CANDLE proposal for the construction of a 3 GeV synchrotron light source in the Republic of Armenia has merit beyond those previously stipulated in this Introduction. Those reasons are specific to the region and arise from consideration of historical circumstances and assessments of the scientific, educational, and economic conditions which exist. These form the basis for considerations as to how best to remedy the problems which exist.
Armenia is a republic arising from the break-up of the former Soviet Union. As in the case of many of the new republics, the transition to a democratic society was accompanied by major upheavals in many of the previously state run enterprises, resulting in the collapse and devastation of the nation's infrastructure. Once productive facilities now lie in a state of decay, with each passing year making it less likely that those facilities will recover. Thousands of highly educated and skilled scientists and engineers continue to abandon their fields of specialization and their positions at once well regarded institutions to seek employment either in less skilled fields or outside of their native country. Efforts to reverse these trends will require some measure of external financial assistance.
There are many possible forms in which such assistance might take place ranging from modest subsistence programs for individual researchers or travel grants, to a bold new effort to upgrade in a single action the scientific capability to levels commensurate with those of other technologically advanced nations. We believe and propose that the later approach is warranted and is the most likely to be successful. We consider the CANDLE project to be a most promising and effective candidate for achieving a turn-around in the scientific enterprises in that area of the world.
In recognition of the goals it is attempting to achieve, the project has, from its onset, set very lofty aims for itself. To begin with, the facility needs to be an international laboratory open to qualified scientists from a wide geographical area. For another, the design for the facility needs to be competitive in its potential with other third generation light sources existing or being considered in other areas of the world. Thirdly, while the standards of

quality of construction needs to be high, cost of developing the facility needs to reflect the lower labor costs in Armenia. Finally, Armenian scientists and engineers need to exhibit their training, expertise, and ability to assume the initiative for developing the proposal and in carrying it out.

The resulting proposal consists of two parts; the first being a Technical Design Analysis and the second a Societal Analysis encompassing the educational, scientific, and economic cases for building the facility in Armenia. Preparation of the proposal has been largely due to the efforts of Armenian scientists with some assistance from U.S. and German colleagues on technical issues and a U.S. Director to oversee the administration of the effort.

The task of building a User base for the project is a requisite for the project. This task is formidable but indications for that support are encouraging. In just the past 3 months, over 70 proposals to engage in research at CANDLE have been forwarded to the organization. Considering that there are thousands of scientists who presently do not have access to synchrotron radiation facilities, this number of expressions of interest is expected to sky rocket once CANDLE proceeds to the construction phase.

In what follows, we present detailed discussions on the project's features, technical, scientific, and cultural. We hope that the reader will realize that a great deal of sound and considerate thought has gone into developing the concept for CANDLE and that the project is one of high merit and which will have a major impact upon science in that region.