All but two years of Richard “Dick” Battin’s career were spent at the MIT Instrumentation Laboratory (IL), its successor The Charles Stark Draper Laboratory, Inc, and teaching MIT graduate students. He intuited solutions to complex dynamics problems, then applied new techniques to address their computational challenges. His focus was development of precision missile and spacecraft guidance. Late 1950s work by Dr. Battin, Dr. J. Halcombe Laning, and Milton Trageser on the design of a spacecraft capable of a round trip Earth-to-Mars mission became the basis for the IL’s 1961 selection to develop the Apollo Guidance, Navigation, and Control (GN&C) system. Battin then led development of the Apollo Guidance Computer (AGC) software. The extraordinary AGC software challenges included fitting all Apollo GN&C functionality within the 38K 16-bit word memory while enabling real-time execution despite a 12 micro-second cycle time. The AGC software met all objectives for all Apollo missions. Battin’s leadership, insights, and collaboration with a brilliant supporting staff enabled this success. He was also a person of strong personal convictions, serving as a moral compass for many. He profoundly believed in and practiced participatory democracy, and led a foundation to facilitate adoption of special needs children.

INTRODUCTION

Richard Horace (Dick) Battin (Figure 1), born in 1925 in Atlantic City, New Jersey, was educated in primary schools in Louisville, Kentucky, and at Forest Park High School in Baltimore, Maryland. He then went on to get an S.B. in Electrical Engineering from the Massachusetts Institute of Technology (MIT) in 1945. Upon graduation from MIT he spent a year in the US Navy as a Supply Corps officer, then returned to MIT as a mathematics instructor and Research Assistant in the Meteorology Department doing basic research on atmospheric circulation. In 1951 he received a Ph.D. in Applied Mathematics from MIT.

Figure 1. Dick Battin in His Office in December 1971.
Upon receiving his doctorate, Battin joined the MIT Instrumentation Laboratory (IL) as a Research Mathematician, working on fire control and inertial navigation systems under the supervision of Dr. J. Halcombe Laning. Except from 1956-1958 when he was employed in the Operations Research Group of the consulting company Arthur D. Little, Battin worked at the IL and its successor The Charles Stark Draper Laboratory, Inc., until 1987. For much of that time and beyond (until 2010) he also served as a Senior Lecturer at MIT, teaching Astronautical Guidance.

Over his career, Battin researched and published in the fields of meteorology, analog and digital Guidance, Navigation, and Control (GN&C) techniques, stochastic processes, astrodynamics, and numerical analysis. Three of the Apollo astronauts who walked on the Moon did their graduate research under his supervision, as did many other talented students including more who became astronauts. He was widely recognized as an inventor of modern space guidance, receiving many awards for both his research and teaching.

INVENTING SPACE GUIDANCE: BALLISTIC MISSILES AND A MARS MISSION CONCEPT LEADING TO APOLLO

In the early to mid 1950s before his brief tour away from the IL, Battin, in collaboration with Laning, formulated guidance principles for ballistic missiles. It began with work to develop a self-contained guidance system for the Atlas intercontinental missile as a backup to Convair. The work was done for the Ramo-Wooldridge Corporation, with the technical monitor being a young James Fletcher who later became NASA Administrator (eventually serving in that capacity twice). Battin subsequently wrote that “with no vast literature to search on “standard” methods of guiding ballistic missiles, we invented one.” This led to a design called “Delta Guidance” that utilized a Taylor series expansion around a reference flight trajectory that met the desired propulsion cut-off criteria. The concept of Delta Guidance was deemed simple, but it was hard to implement using the analog electronics capabilities of the time. During a trip to Convair by Battin in 1955, he got insight from the Convair engineers that the powered-flight velocity-to-be-gained vector eventually becomes nearly parallel to a fixed direction in inertial space. He realized that this meant that the guidance algorithm should aim to drive the velocity-to-be-gained to zero. He debriefed this to Laning, who after several weeks formulated the idea to base guidance on a differential equation for velocity-to-be-gained, but the focus of this revelation and ensuing work was no longer for the Atlas missile program.

By 1956 Battin and Laning used their new insight to create an algorithm that was a crucial enabler for the Air Force Thor missile program and which also found subsequent application to the Polaris missile program. Fundamental to the guidance concept they developed was the simple, but at that time entirely novel concept of Battin’s that by aligning missile thrust with the vector difference between the current velocity and desired velocity (the velocity-to-be-gained), the vehicle will go where you want it to go. The resulting guidance algorithm formulation was based on vector matrix equations with a key symbol “Q”, so the resulting algorithm was dubbed Q-Guidance. The Q-Guidance algorithm saw first flight use on Thor in late 1957. Battin and Laning also recognized, based on early-era digital computer computational studies, that the fuel-optimal steering of burns could be realized based on the cross product of the velocity-to-be-gained vector with its time-rate-of-change vector (cross-product steering) that was later formally derived in a MIT doctoral thesis by Fred Martin.

During this period, Battin co-authored a book with Laning regarding how stochastic processes impacted automatic control that found wide application in graduate classrooms and the industry.

Motivating Battin’s return to the IL in 1958 was his interest in working on interplanetary navigation and guidance for a Mars Probe system design study sponsored by the Air Force that was
being pursued by Milton Trageser and Laning. Soon thereafter Battin found that there were not yet systematic means for computing trajectories for simple two-body, two-point boundary value problems (i.e., time-of-flight constrained inter-planetary transfer trajectories – needed for Mars Probe mission analysis)\(^1\), also known as Lambert’s problem. This problem was named after the 18\(^{th}\) century mathematician Johann Lambert who made major contributions to understanding the basis for planetary orbital dynamics. Battin sought to address Lambert’s problem, and he made significant initial contributions by eliminating both a sign ambiguity in a solution and an asymptotically infinite slope as a minimum energy solution was approached that could prevent successful computation of a solution by a computer. Battin did away with these issues by making a different choice of independent variable along with a new method to obtain the initial velocity vector.\(^1,5\) Use of this Lambert’s problem solution method was soon adopted by the Jet Propulsion Laboratory (JPL) for interplanetary mission applications as well as by the Navy and Air Force for ballistic missile targeting.

The Mars Probe mission concept was to send a probe to fly by Mars, take a photo in close proximity (using film as the technology of the day), and then return the spacecraft to Earth to recover the film with the photo.\(^6\) The architecture of this mission, with the functionality as depicted in Figure 2 and a resulting vehicle design as depicted in a mockup shown in Figure 3, formulated the basis for proposed interplanetary flight GN&C, including planned use of an early version of a spacecraft digital computer that would host the GN&C autopilot. This digital GN&C system architecture combined with the Polaris missile navigation system (also developed at the IL) would become the basis for the Apollo GN&C system. Battin recognized that spacecraft navigation state aiding updates could be accomplished by using a telescope to do both star and lunar/planetary limb sightings, and accurate navigation estimates could be maintained using recursive processing of inertial instrument data with account for the celestial equations of motion.\(^7\) It was during this part of Battin’s career when the principles for deep space guidance and navigation algorithms were developed, and when he drafted what became a text book that documented these principles and saw use in his MIT Astronautical Guidance course.\(^8\) It was also during this time period that Battin explored efficient interplanetary transit trajectories. This included what was likely the first detailed study of the critical importance of accounting for non-planar and non-circular characteristics of planetary orbital dynamics when addressing interplanetary trajectory design.\(^5\) Subsequently, but also in this time period, Battin investigated faster
interplanetary transit trajectories that could be designed using gravitation assist of celestial bodies as shown in Figure 4 in which Venus served that purpose. While the concept of gravity assist was first recognized a few years earlier (1956) by G.A. Crocco, that work assumed coplanar, concentric circular planetary orbits.

In August 1961, NASA issued the first Apollo contract to the IL at which time Battin assumed responsibility for creating the guidance and navigation concepts to be implemented in the onboard Apollo Guidance Computer (AGC). He became the Director of Mission Development for the MIT Apollo program, heading a large team of analysts and programmers. At the same time, David Hoag who had been Technical Director at the IL for Polaris assumed the role of Technical Director at the IL for Apollo to leverage his highly successful system integration experience from the Navy work for the benefit of Apollo. Battin and Hoag would work together in these capacities for the duration of the Apollo program.

Figure 3. J. Halcombe Laning, Milton Trageser, and Richard Battin (left to right) with a Mockup Model of the Proposed Mars Probe Spacecraft.

Figure 4. A Trajectory Found by Battin for the Mars Probe Concept with Outbound (7/9/66) and Return (9/1/67) Venus Gravity Assist Flybys That Would Have Reduced the Round Trip Mission Times to Less than 23 Months.
DEVELOPMENT AND SUCCESS OF THE AGC

The AGC evolved from the Mars Probe computer design which was prototyped by the IL. The Mars Probe computer had 4096 16-bit words of fixed core rope memory, and 256 words of erasable memory with a cycle time of 24 micro-seconds. (Note that one of a word’s 16 bits was dedicated to parity check, leaving 15 bits for computational use.) The AGC went from an initial design concept with 12,288 16-bit words of fixed core rope memory and 1,024 words of erasable memory to its final flight configuration to 36,864 16-bit words of core rope memory and 2,048 words of erasable memory (38K words of total memory). One AGC each was assigned to the Apollo Command Module (CM - that took the three-member crew from Earth orbit to Lunar orbit then back to Earth), and to the Lunar Module (LM - that carried two members of the crew from lunar orbit to the lunar surface and then back to lunar orbit). When the AGC software development work was initiated in 1961, it was intended to manage CM and LM flight functions, providing guidance and navigation capability. In June 1964 NASA directed that all the Apollo spacecraft autopilot functionality, including vehicle control, also be performed digitally in software on the AGCs. To accommodate that added computational throughput burden, the IL was authorized to update the computer design to enable a doubling of the computer speed to a cycle time of 12 micro-seconds.

The IL gathered some extremely creative engineers onto the AGC software development team to serve under Battin in his capacity as Director of Mission Development. That team had to enable all Apollo CM and LM mission management and GN&C autopilot functionality to fit within the AGCs limited memory and throughput capacity.

The starting point for the AGC GN&C software was navigation strategies and algorithms developed for the Mars Probe. Navigation updates were to be obtained by measuring angles between planets and stars (that could be emulated by an Apollo crew member using a sextant), and then a Gaussian weighted least squares method was to be used to obtain a celestial fix. The navigation algorithm was to be processed recursively in what would become an early form of a state estimator. (This design was formulated by Battin for use on the Mars probe in the late 1950s, and only later was recognized as equivalent to the subsequently developed Kalman filter.) However, given the computational precision limits of the AGC, direct recursive filtering of the navigation state was very problematic. For example, when using the original navigation filter design concept, cumulative numerical errors after making multiple navigation reference state updates were found to cause the covariance matrix to become non-positive definite, which prevented successful filter function. However, one of the young engineers on Battin’s design team, Dr. James Potter, conceived a new square-root formulation of the filter that precluded the possibility of non-positive definite conditions. (This was a kind of “outside of the box” thinking utilized repeatedly by the AGC software team to overcome Apollo design challenges.)

Most of the guidance and control software functionality was newly designed for Apollo, based both on the specifics of the mission flight profiles and the CM/LM spacecraft physical characteristics. (Early Apollo missions involved suborbital and Earth orbit tests, eventually followed by lunar orbit tests and landing missions.) However, much of the applicable analytic and algorithmic foundation for the guidance was based on Battin’s prior work. The CM guidance functions included attitude maneuvers, attitude hold, and trajectory changes. The LM guidance functions also included lunar descent and ascent. What were then quite new control concepts such as phase planes for attitude control when using discreetly on-off (“bang-bang”) thrusters were incorporated into the CM and LM software designs. CM and LM control algorithms addressed differing reaction control system and main propulsion system properties on the two vehicles as well as vehi-
cle-specific mass properties, flexure behavior, and propellant slosh characteristics. The LM also had landing and rendezvous radar systems as added navigation sensors.12

A central design consideration for Apollo missions was accommodating the AGC operation oversight by a crew. This was accomplished with a Display and Keyboard (DSKY – see Figure 5) that provided an interface for crew management of the AGC software execution including for their initiation of critical software-managed mission events.12,17 The DSKY also provided means for the crew to direct/manage changes to mission execution under contingency conditions. A significant DSKY function innovation developed by Alan Green (who was on Battin’s AGC software team) was to structure inputs by the crew into numeric code sequences, each including a “verb”, and a “noun”. That enabled the crew to think of their AGC/DSKY interactions like language. A verb code would direct a type of action like “display”, “load”, or “execute”. A “noun” code would identify what required application of the directed action such as a “gimbal angles” to be displayed, a “star number” to be loaded, or a particular “program” to be executed (as would be done for a trajectory change burn).

Because of the expected central role of the AGC and its software during Apollo flights, key NASA personnel often visited the IL to meet with Battin and other AGC development team leaders at the IL as seen in one example in Figure 6. Also, early in the flight test program, the IL had the most capable facility for training the crew on GN&C/AGC flight operations. This brought mission primary and backup astronaut crews to the IL to meet and train with the AGC hardware and software development teams as seen in Figure 7.

The AGC software made the Apollo spacecraft the first digital fly-by-wire aerospace vehicle. This was accomplished with “little or no history to work from … (Battin’s) team had to come up with methods for both the development and verification of the software….” In this capacity Battin “set the standard of excellence … making complex mat-

Figure 5. The DSKY That Was the AGC Interface With the Apollo Crew

Figure 6. Werner Von Braun (in the middle with Battin to his immediate right) During a Visit to the IL for Apollo System Discussions on May 6, 1964. That is an IL Apollo System Design Report Von Braun Has in Hand.
ters seem simple… . Methods developed under his leadership … are still in use today to develop
and verify mission-critical software….***18

There were several unmanned Apollo flight tests using the AGCs, and subsequently 15 Apollo-
lo, Skylab, and Apollo-Soyuz missions with crews. The computers successfully performed all
missions without failures despite some dramatic vehicle hardware anomalies such as the Apollo
13 service module explosion that forced use of the LM AGC and propulsion system to enable the
CM/LM stack to return the earth (using software capabilities developed at the IL that had antici-
pated just such a contingency).12 The total Apollo software design effort from the beginning
through the initial lunar landing by Apollo 11 in 1969 was 1400 man years, peaking at 350 man
years in 1968.12

Figure 7. The Apollo 1 Primary and Backup Crew at a Meeting with the AGC Development
Team, on August 11, 1966. The Astronauts Are in the Front Row With (left to right) Gus
Grissom, Roger Chafee, David Scott, James McDivitt, Rusty Schweickart, and Edward
White, with Battin at the far right in the back.

PROVIDING THE PUBLIC WITH A HISTORICAL PERSPECTIVE OF SPACE TRAVEL

Battin was not only a skilled educator of aerospace graduate students, but was also a very gift-
ed writer and speaker. He was very knowledgeable about the history of advances that enabled
humans to navigate and guide across long distances, initially on the seas, and then during his life-
time in space. Over the span of his career he used this knowledge to communicate why space
exploration was important to humanity, and how it was being accomplished.
Early in his career, when the space program was in its infancy, in a public speaking engagement he addressed why his generation should pursue the challenge of space exploration. He said that “Our heritage of the great works of science has certainly made our lives undeniably richer and it is up to us to insure that our grandchildren will be able to say the same of us. If we cannot meet the challenge of our generation, then we truly do not deserve to belong to this generation.”

The public outreach by Battin that got the widest dissemination was during the Apollo 8 mission. As part of its coverage of humanity’s first voyage from the Earth to the Moon, The New York Times ran a lengthy article by Battin (Figure 8) addressing how old navigation theories were as important as the AGC in making the mission possible. In this article that was written lucidly for the general public, he laid out the history of human navigation advances from the astrolabe used by the Greeks over 2000 years ago to determine north/south position (latitude), to the chronometer developed by John Harrison in the 18th century to enable determination of east/west position (longitude), and on to the methods used by Apollo for cis-lunar flight. This article enabled the readers in the public to grasp both the fundamentals of how navigating to the Moon was being accomplished and also how the achievement of guiding a vehicle with a crew to and from our celestial neighbor was part of a lengthy sequence of theoretical and technical achievements over the course of human history.

Figure 8. Part of a Battin Article Published by the New York Times on December 21, 1968 During Apollo 8.

In 1989 on the 20th anniversary of Apollo 11, multiple Boston area media outlets ran articles about the Apollo missions based on interviews with Battin. He used these opportunities to convey to the public some of the extraordinary experiences associated with development and flight application of the AGC software, and the emotions he felt during the missions.

- Regarding the uncertainty faced when work on the Apollo started: “We had underestimated the software task … Nobody had ever done a job like that before and we were just guessing on how long it would take and how many people would be needed.”
- Regarding how thorough preparation helped assure the lunar landing success of Apollo 11 despite multiple AGC overload alarms during terminal descent: These “alarms had sounded for the first time in a simulated flight just two weeks before Apollo 11 lifted off for the moon. At the time the alarm had surprised the computer’s designers. We said we didn’t want any surprises on the moon….So we ordered a complete review of every possible computer alarm.
If the review hadn’t been done, … Mission Control wouldn’t have fully understood the computer alarms and probably would have ordered an abort for the landing.”22 (Note that while the alarms indicated that there were computer overload conditions, under such circumstances the computer software was designed to resolve the overload by automatically focusing only on what was high priority at the moment, stopping the processing of what was not then needed – an innovation devised by Laning. In the case of Apollo 11, the added processing burden of the LM’s rendezvous radar that was turned on by a crew member during the lunar landing phase was the cause of the overload, but the rendezvous radar was not needed for landing, so its processing was precluded.)

- Regarding Battin’s greatest emotional highlight from the Apollo program: “Certainly the longest and most thrilling five minutes of my life was the ... burn of the S-IVB [Saturn] engine to boost the speed of the Apollo 8 spacecraft to the 24,200 mph necessary to escape the Earth.”23

**CONTINUING SPACE GUIDANCE ADVANCEMENT**

From the late 1950s on, Battin never stopped looking for ways to improve the computational basis for solving Lambert’s problem (i.e., determining interplanetary transfer trajectories). He addressed this interest both individually and in collaboration with some of his graduate students and IL staff colleagues. His pursuit of ever better Lambert’s problem solution methods was driven by the technical challenges posed by proposed mission applications, but he also got much delight in finding new insights into this geometric and computational problem. The following were the most compelling technical challenges:

- Limiting the Lambert’s problem solution computational burden to enable the associated algorithm use in real-time onboard spacecraft.
- Eliminating as many computational singularities in the solution method as possible to assure that a single solution algorithm could be applied to the widest possible classes of orbit transfer applications.
- Assuring solution convergence, which was essential if an algorithm was to be implemented as a flight critical function.

As addressed previously, Battin’s first effort at tackling the Lambert’s problem was in 1959 when he eliminated a sign ambiguity and a minimum energy solution convergence challenge by introducing/applying a new independent variable.5

In a 1968 conference paper 24 (for which the proceedings were published in 1970), Battin derived a new Lambert’s problem solution in which the time of flight is a sum of two hypergeometric functions expressed in terms of a newly defined independent variable, with the resulting terminal velocity vectors having a relatively simple formulation. This Lambert’s problem solution was found to be computationally effective for elliptic and hyperbolic orbits, but breaks down for parabolic orbits. To enable addressing the parabolic orbit case, Battin developed algorithms based on a power series and continued fraction expansions which are continuous near and at a parabolic orbit condition.

In a 1977 journal paper 25, Battin focused on further generalization of a solution to Lambert’s problem, but also with an emphasis on computational efficiency to better enable its use in real-time as part of a powered flight guidance algorithm. The derived time-of-flight equation was found applicable to elliptic, parabolic, and hyperbolic trajectories. He leveraged an independent variable conceived by others26 to derive his solution with only one hypergeometric function that was expressed as a continued fraction, which for many applications required only one square root function evaluation per guidance iteration cycle. This paper’s solution was compared to the need
to compute two hypergeometric functions per iteration cycle using the Lambert’s problem solution in his prior paper.24

In a 1978 journal paper27, Battin with two co-authors addressed a corollary to Lambert’s problem to reformulate the two-planetary-body two-point boundary-value orbit transfer problem into a simpler form that could be solved using a means analogous to the method of successive substitutions. This derived solution formulation applied to elliptic, parabolic, and hyperbolic orbits.

A 1984 journal paper co-authored by Battin and his graduate student Robin Vaughn28 brought to a conclusion a more than 25-year effort by Battin to develop ever more practical and universal solutions to Lambert’s problem. This paper’s solution exploited a principle of invariance addressed in the previously discussed paper27 which applies under a particular geometric transformation, and enables the transformed problem to be described using Kepler’s equation. This 1984 paper also introduced a free parameter into Kepler’s equation that could insure very rapid convergence over the entire range of orbit transfer scenarios. The singularity at 180 deg orbit transfer angle applicable to previous solution methods was removed. The only singularity remaining was for 360 deg orbit transfers. The number of numerical iterations needed to converge to a solution with high precision was found to be very small, except when exceedingly close to the 360 deg transfer orbit singularity case.

In 1986 Allan Klumpp of JPL (and previously of the IL) informed his colleagues about the latest Lambert’s problem solution by Battin and his graduate student Robin Vaughn,28 saying that they had produced “a remarkable new algorithm” with the following advantages:

- Compactness, speed, and reliability for spacecraft onboard guidance.
- Accuracy.
- Elimination of singularities except for 360 deg equi-radius orbits which have no practical importance.
- A single iterative solution method everywhere.
- No requirement for a reference trajectory.29

After Battin’s death, a memorial tribute from the National Academy of Engineering noted that the evolved approach to Lambert’s problem resulted in a “universal solution to this problem (that) holds for the entire energy range, covering elliptical, parabolic, and hyperbolic transfers, eliminating all classical singularities except those where the orbit plane is inherently not unique.”

A LIFE LED AS A PATRIOT AND MORAL EXAMPLE

Throughout his adult life, Battin felt a moral duty to serve in our participatory democracy while protecting both core democratic values and disadvantaged members in his community. He was an elected Town Meeting Member in his home community of Lexington, Massachusetts for 53 years, including 6 years of service as Vice-Chair of the Lexington Appropriation Committee. He also served as President of the Board of Project IMPACT for 9 years, facilitating adoptions of special needs children.

Dr. Battin’s passion for public service was a partnership with his wife of 65 years, Margery Milne Battin. She served on the Town Meeting in Lexington for 49 years and led a successful effort to modernize the town government to be more responsive to the resident needs. After that modernization, she served as Selectman for 12 years (Figure 9) including as Board Chair, and subsequently 22 years as Moderator. She was the first woman to be President of the Massachusetts Selectman Association and also the Massachusetts Moderators Association (the only person to be President of both). This was in addition to her service to innumerable groups addressing human needs. She saw “the conduct of local officials and representatives – the way they can ve-
hemently disagree with each other year after year and continue to respect each other – as a model that ought to be emulated on the national level."

In Dr. Battin’s personal archives I found two unattributed hand-typed essays from the 1940s that make the following points:

- The first essay addresses the responsibilities of individual Americans under the Constitution. It observes that “Our liberty and freedom, guaranteed by the Constitution, have a price tag demanding payment of “eternal vigilance.” Eternally keeping watch for destructive forces which are now attempting to destroy our Constitution …. They must be guarded against. This is our responsibility. We must accept it.” It goes on to say that “Real Americans endeavor to raise human rights to a high level and to keep them there as long as they do not interfere with the rights of others. They maintain their own sovereignty without menace to the dignity of others.” It then observed that “True Americans recognize their responsibility. They realize that they are the government – governing themselves …. that as Americans they must cast aside former complacency and smugness; and in international fields, they must discontinue previous selfishness and superior attitude.”

- The second essay addresses the necessary role of educational institutions in a “free and democratic land,” the United States. It states that “our public schools do more than just turn out graduates whose minds are storehouses of learning. They also turn out … graduates who

* April 19 is the anniversary of the 1775 Battle of Lexington and Concord that stated the Revolutionary War, with the first shots fired on Lexington Green. Its remembrance and celebration is a big event each year in Lexington.
have learned to love beauty and respect others as themselves …. Who have learned that co-operation is not a sentiment but an economic necessity.” It then observes that “We Americans are, therefore, permitted to have differences of opinion, differences in politics, differences of, oh, so many kinds – and yet, be friends.”

The two essays reflect core beliefs shared by Dr. Battin and his wife. I cannot be sure which of them wrote the essays, but from my personal exposure to them I know the essays reflect values they both lived.

In a Project IMPACT newsletter Dr. Battin correlated his experience from the Apollo program and his interest in the Project IMPACT. He noted that the “national goal of landing man on the moon …. was … like an impossible dream.” He went on to state that “Project IMPACT set … an exciting challenge – another dream …. To prove that all children are adoptable …. Not just the beautiful new-born babies but all children – the physically and mentally handicapped as well as the older child with a long history of abuse and rejection.”

Given his moral compass, one may wonder about the basis of Battin’s commitment to his chosen career path. He provided that reason: “… many of the greatest achievements, where the object was pure knowledge alone, have led to the material advantages for present and future generations which were undreamed of by those chiefly responsible for their accomplishment.”

Dr. Battin’s career achievements as a mathematician and engineer were extraordinary, but he had no sense of entitlement as a result. Instead he felt an on-going obligation to contribute as much service as possible to his community, to his fellow Americans, and to humanity. He was a shining example of personal decency and morality as well as of technical brilliance.

SOME OF DR. BATTIN’S ACCOLADES

Over the course of his career Battin received much acclaim for his extraordinary technical contributions and highly consequential Apollo software team leadership accomplishments. Some of the most significant recognition he received is listed below. Most of the awards he received were individual, but notably the AIAA Louis W. Hill Space Transportation Award was shared with his close friend and IL colleague, David Hoag (seen with Battin in Figure 11). Without the complementary leadership roles provided by both Battin and Hoag, the IL’s Apollo GN&C system development would not likely have been so successful.

Major Awards & Recognition for Dr. Battin
1. 1970: Fellow of the American Institute of Aeronautics and Astronautics (AIAA)
2. 1971: Elected Member International Academy of Astronautics
3. 1972: AIAA Louis W. Hill Space Transportation Award
4. 1974: Member of the National Academy of Engineering
5. 1978: AIAA Mechanics and Control Flight Award

Figure 11. Dave Hoag (left) and Dick Battin (right) in a Lunar Module Simulator About the Time They Received the AIAA Hill Transportation Award. Note the DSKY by Battin’s right hand.
7. 1987: AIAA Pendray Aerospace Literature Award
8. 1989: AIAA von Karman Lectureship Award
9. 1990: Honorary Fellow of the AIAA
10. 1996: AAS Dirk Brouwer Award
11. 2000: Institute of Navigation (ION) Tycho Brahe Award
13. 2002: AIAA Summerfield Book Award

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Note that any figures not explicitly tagged regarding their source were acquired from the archives of The Charles Stark Draper Laboratory, Inc. (Draper), including the personal office archives of Dr. Battin held by Draper.

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