Aerospace Engineering

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College of Engineering

The University of Michigan: A Encyclopedic Survey

The University of Michigan: An Encyclopedic Survey was first published beginning in 1942. For its 2017 Bicentennial, the University undertook the most significant updating of the Encyclopedia since the original, focusing on academic units. Entries from all versions are compiled in the Bicentennial digital and print-on-demand edition.

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Aeronautical Engineering (1942)

Emerson W. Conlon

IN 1911 Professor Herbert Charles Sadler (Glasgow '93, D.Sc. hon. ibid. '02, LL.D. ibid. '27), chairman of the Department of Naval Architecture and Marine Engineering, attended the first International Aviation Meeting at Boston, Massachusetts. Many of the great contemporary flyers, including the Wright brothers, Glenn Curtiss, Louis Bleriot, and Graham White, took part in the airplane races and exhibition flights held on that occasion.

Interest in aeronautics was traditional in Sadler's family, for his great-granduncle, James Sadler (1751-1828), of Oxford, was the first English balloonist, and the two sons of James Sadler, Windham and John, followed their father's hobby and career. J. E. Hodgson in his voluminous History of Aeronautics in Great Britain devoted an entire chapter to the Sadlers (Chap. VI, "The First English Aeronaut, James Sadler and His Sons").

Moreover, during his early teaching career at the University of Glasgow, Sadler had as his colleague Percy S. Pilcher, who was Otto Lilienthal's follower and the British pioneer in modern glider flying.

Upon his return from the aviation meeting in Boston Sadler reorganized the University of Michigan Aero Club. In the year 1911-12 the students built a small wind tunnel in the "mold loft" of the West Engineering Building and experimented with various kinds of craft. They also built a glider, patterned to some extent on the Wrights' biplane, and flew it as a kite in the hilly country surrounding Ann Arbor. Since they had had no aeronautical experience, they concentrated on controlling the rise and descent of their craft and on maintaining its longitudinal equilibrium, depending for the more difficult lateral equilibrium on two helpers standing on the ground and holding ropes attached to the wing tips. The ground helpers were often lifted into the air by sudden gusts of wind or by the pilot's abrupt use of the elevator control. Sadler helped and advised, repeating the warning given him by Wilbur Wright: "If you will advise them [the students] to build a glider and to fly it, do not let them build it too light."

In 1910 Felix Wladyslaw Pawlowski (Paris '10, M.S. Michigan '14), who had taken the first course in aeronautical engineering ever given, that of Lucien Marchis at the University of Paris, arrived in this country. He spent two years in Chicago as a designer for the automobile industries. In 1911-12 he wrote to a number of engineering colleges and technological institutes requesting an opportunity to develop courses in aeronautics. He received negative replies from most of them on the grounds that aviation "very likely" would never amount to anything. But he had two encouraging answers, one from the Massachusetts Institute of Technology expressing interest in the proposal, although declining it "for the present" because of lack of funds, and another from Dean Mortimer E. Cooley, which resulted in Pawlowski's appointment to the University of Michigan in 1913 as Teaching Assistant in Mechanical Engineering, with the understanding that later he would be permitted to introduce courses in aeronautical engineering. He became Instructor in 1914.

In view of the times and the stage of development of aviation, it is easy to find justification for the negative attitude of the various deans approached, but the farsightedness of Dean Cooley as well as his confidence in the future possibilities of this

new mode of transportation is evident. When he presented the matter to his standing committee, Sadler and Ziwet expressed their approval.

After Pawlowski's arrival at the University interest in aviation increased rapidly. For a time, partly because of his insufficient command of the English language and partly because aeronautical engineering was not yet considered important (Cooley, Scientific Blacksmith), Pawlowski's official duties were limited to drawing-room work in mechanical engineering. He took a leading part in the activities of the Aero Club, however, thus relieving Sadler of that responsibility. Once a week the club held regular meetings, during which principles of aerodynamics and aviation were discussed, and another larger, but not a better, biplane glider was built. This glider also was flown as a kite, and, probably for the first time in the history of aviation, an automobile was used to tow it. Two students, Flavius E. Loudy ('16e [Ae.E.], Ae.E. '38) and Lewis C. Wilcoxen ('16e), distinguished themselves particularly in connection with the construction and the handling of this glider. Loudy later had a successful career in the aeronautical industries and in the Bureau of Aeronautics of the Navy Department.

The enthusiasm following a series of lectures delivered at the University in the fall of 1913 by Professor Lucien Marchis contributed to the establishment of the first regular courses in aeronautics in February, 1915. Professor Marchis throughout his earlier career had been interested primarily in the industrial or practical applications of physics; thus he lectured successively on the theory of steam engines, internal combustion engines, automobiles, and on aeronautics.

These first courses at the University, which were under the direction of Pawlowski, proved to be so popular that it was necessary to extend and correlate them as one of the regular groups of electives. This instruction, however, was for members of the Aero Club and was offered without credit. John H. Ledebaer's translation of Duchene's Flight Without Formulae was used as a textbook. The regular courses in aeronautical engineering, leading to a professional degree, were organized as a group of electives in the Department of Naval Architecture and Marine Engineering. Only junior and senior engineering

students were eligible. The curriculum was much like that for naval architecture and marine engineering students and was similar also to the course in mechanical engineering. The aeronautical subjects were added partly at the expense of the electives.

The first course, Theory of Aviation, introduced in 1914-15 for two hours of credit, dealt with the principles of aerodynamics and the mechanics of flight. Students who were members of this first class included D. M. Bavly, M. L. Goldstein, K. W. Heinrich, A. Horbaszewski, Yocham Hu, F. E. Loudy, and Chien Hsün Sung.

In 1915-16 two new courses in aeronautics were added, Propulsion of Aeroplanes, which dealt with propeller design and the principal features of the various types of motors, and Aeroplane Design, which consisted of lectures and drawing room work. The details of the actual construction of an airplane were discussed, and a design was made to fulfill a given set of conditions. Sixteen students were enrolled in the three courses during the year.

A 1912 model "B" hydroplane, manufactured by the Wright brothers, was presented to the University Aero Club in 1915 by Russell Alger, of Detroit, president of the Michigan Aero Club, and Frederick W. Alger, of Clarkston. Shortly afterward, the machine was destroyed in a trial flight on Barton Pond, fortunately without any harm to the pilot.

In 1916-17 a complete four-year program of study, Program VI, leading to the bachelor's degree in aeronautical engineering was arranged. The department was included in the then renamed Department of Naval Architecture, Marine Engineering and Aeronautics. Pawlowski, as Assistant Professor of Mechanical Engineering, still taught certain courses in mechanical engineering. During this year the following aeronautical courses were offered: General Aeronautics, Theory of Aviation, Theory and Design of Propellers, Aeroplane Design, Aeronautical Laboratory, Design of Aeronautical Motors, Theory of Balloons and Dirigibles, Design of Balloons and Dirigibles, Theory and Design of Kites, Design of Aerodromes and Hangars, Advanced Stability, Aeronautics — Advanced Reading and Seminar, Aeronautics — Advanced Design, and

Aeronautics — Advanced Research. General Aeronautics was added as an introductory course dealing with the fundamentals underlying the design and performance of both the lighter-and the heavier-than-air craft.

Of the fourteen courses proposed and listed, only the first six were required as a minimum qualifying the student for the degree in aeronautical engineering; the remainder were offered as electives in accordance with the needs of senior and graduate students. During the first semester General Aeronautics was taught by Sadler, and Theory and Design of Propellers, Aeroplane Design, Advanced Reading and Seminar, and Advanced Aeroplane Design were offered by Pawlowski. At the end of the first semester of 1916-17 Pawlowski was granted a leave of absence to accept a position in Washington, D.C., as aeronautical engineer for the United States Army.

During the second semester the following courses were offered: General Aeronautics (Sadler), Theory of Aviation (Gerhardt), Aerodynamic Laboratory (Sadler), and Design of Aeronautical Motors (Fishleigh).

In May, 1917, the degree of bachelor of science in engineering (aeronautical engineering) was established, and in June, 1917, William Frederick Gerhardt was the first student to receive it.

Owing to the important role of aviation in World War I, the War Department began to organize design and construction of airplanes for the United States Army, and for that purpose drafted engineers who possessed some knowledge of aviation. After the declaration of war, however, and upon the arrival of the Balfour-Viviani Mission, the War Department accepted the advice of these experts of our Allies and abandoned attempts to develop original airplane design, concentrating instead on the utilization of the enormous manufacturing facilities of the country for quantity production of aircraft of Allied design. Consequently, in the fall of 1917, Pawlowski returned to the University to assist in conducting a special course, Principles of Aviation, which permitted students drafted into the Army to qualify or to claim preference for Air Corps service. The courses given during this year were: General Aeronautics, Theory of Aviation, Propeller Design, Airplane Design, Aeronautical Laboratory, and Aeronautical Motor Design. A two-hour course

in "ground" instruction for future flyers was open to students from other schools and colleges on the campus. Because of the large enrollment in Theory of Aviation, it was taught in two sections. In June, 1918, four students qualified for the degree of bachelor of science in engineering (aeronautical engineering), and W. F. Gerhardt, the first student to qualify for an advanced degree in aeronautics, was granted the degree of master of science in engineering (aeronautical engineering). Pawlowski was promoted to an associate professorship of aeronautical engineering and was relieved of further teaching duties in mechanical engineering.

During the first semester of 1918-19, work in aeronautical engineering was conducted by Pawlowski alone. Most of the thirty-four students in the first course wished to qualify for service in the Air Corps. Ten students enrolled in the courses offered in the second semester, only two of whom qualified for the bachelor's degree. The two built a dynamometer for the small wind tunnel.

Pawlowski was granted leave of absence during the first semester of 1919-20 to organize aeronautical research for the Polish army. In 1920-21 he taught all of the courses except Dynamic Stability, which was given by Professor Ziwet, of the Mathematics Department. Thirty-seven students were registered in aeronautical engineering during this year, and eight were graduated with the bachelor's degree.

Edward Archibald Stalker ('19e[Ae.E.], M.S.E. '23), after two years of experience in airplane design with the Stout Engineering Laboratories, Dearborn, Michigan, was appointed Instructor in Aeronautical Engineering in 1921 to relieve Pawlowski of part of his teaching load in order that he might have time for original investigations.

Plans for the East Engineering Building provided for a new wind tunnel, and in 1924 Pawlowski visited Europe to study the development of aeronautics and to obtain information to aid in the installation of the wind tunnel, which was finally completed with the aid of a gift of $28,000 from the Guggenheim Fund in 1926. An additional amount of $50,000 from the same fund was also given to provide a professorship of applied aeronautics for ten years. Lawrence Vincent Kerber ('18e [Ae.E.], A.E. '36),

who was appointed to this position, came to the University in February, 1927. He assisted with the instruction in design and developed a course in aerial transportation, the first to be given by a university. One project undertaken in 1928-29 led to Professor Stalker's discovery that sucking off the boundary layer (the thin layer of air at the surface of a wing) is an effective method of delaying wing "stalling."

In January, 1927, the staff, assisted by members of other departments and by officers of the Naval Reserve Corps of Detroit, conducted a newly approved course in naval aviation to train men for the Naval Reserve Air Force. In 1928 the department purchased a discarded plane from the government for use in this course.

In 1929-30 the department, with 254 students, had the largest enrollment in the College. A total of 129 bachelor's degrees, eighteen master's degrees, and one doctor's degree had been granted by the end of 1929. Walter Francis Burke (Massachusetts Institute of Technology '29, M.S. Michigan '32) was appointed Instructor in this year. A committee composed of Professors Pawlowski and Stalker, Assistant Professor Frank N. M. Brown ('28e[Ae.E.], M.S.E. '32), who had come in 1928, and W. Burke administered the work in aeronautical engineering. Pawlowski was appointed to the Guggenheim professorship formerly held by Professor Kerber, who had resigned in 1929, following a year's leave of absence with the Department of Commerce.

During the year a new balance, which required only one man for operation, was constructed. This improvement facilitated various research projects. The facilities of the Aerodynamics Laboratory were used by a number of companies, including the Goodyear Tire and Rubber Company, the General Tire Company, and the Stout Engineering Laboratories.

According to the Regents' Proceedings of September, 1930, almost twenty years after Dean Sadler and Professor Pawlowski had roused interest in aviation at the University of Michigan, "The Department of Aeronautical Engineering was established as an organization separate from the Department of Marine Engineering with which it has to this time been merged." In November, Professor Stalker was appointed head of the department.

With the depression enrollment began to drop until by 1933-34 it had reached a low of 176 students. A few changes in staff took place in these years. Milton John Thompson ('25e [Ae.E.], M.S.E. '26, Sc.D. Warsaw '30) was appointed Assistant Professor of Aeronautical Engineering in 1930, and in 1933 Burdell Leonard Springer ('32e [Ae.E.], M.S. '33) replaced Burke, who requested a leave of absence to accept a position with the General Aviation Corporation.

Research became increasingly important in the development of the department. The wind tunnel was used to conduct tests for industrial concerns, and a study of the downflow of gases behind power plant gas stacks and other experiments were carried out as a result of the acquisition of a multiple-tube manometer and a darkroom for photographic work. New equipment was acquired as the need for it arose. A suction blower and auxiliary equipment were installed to test the resistance of automobiles by streamlining. With the aid of C.W.A. labor in 1933-34, a propeller dynamometer, a small portable smoke tunnel, and a dynamic stability dynamometer were completed. In 1934 a small wind tunnel was constructed with the aid of F.E.R.A. and N.Y.A. labor. This tunnel was a single-return type with a cross section twenty-one inches by thirty-two inches at the experimental chamber.

In 1935-36 both Professor Pawlowski and Professor Stalker were granted leave of absence because of illness, and Edward Irwin Ryder ('33e [M.E.], M.S.E. '34), of the Hammond Aircraft Company of Ypsilanti, was appointed Teaching Fellow in order to lessen the teaching load. Milton J. Thompson was made acting chairman of the department in the absence of Stalker.

The Army and Navy in 1935-36 began to send graduate officers to the University for instruction in aeronautics. A larger staff was needed in order to improve the courses offered and to develop a program of research. Charles S. J. MacNeil, Jr. (Massachusetts Institute of Technology '33e[Ae.E.]), was engaged as Lecturer during the second semester of 1936-37 to handle advanced work in aircraft propellers and performance. The student branch of the Institute of the Aeronautical Sciences was organized during the year with Springer serving as honorary chairman.

Research projects were completed by the staff for such groups as the National Advisory Committee for Aeronautics, Beech Aircraft Corporation, United Electric and Manufacturing Company, the Bell Aircraft Corporation, and the Wincharger Corporation. Extensive commercial tests of a one-tenth scale model of the "Electra," America's first all-metal transport airplane, were conducted for the Lockheed Aircraft Company of Burbank, California. These tests were later substantiated by flight tests of the production airplane. One student, Clarence L. Johnson, who had helped with the tests, later became chief research engineer for the Lockheed Aircraft Company. He also received the Sperry Award in 1938.

In 1937-38 Emerson Ward Conlon (Massachusetts Institute of Technology '29e [Ae.E.]) was appointed Instructor to fill the vacancy caused by Springer's resignation, and Stalker resumed his duties as chairman of the department.

Two new design courses, Airplane Structures Laboratory and Applied Aerodynamics, were added to the curriculum in 1938-39. Upon completion of a pilot-training course which was set up in 1939 under sponsorship of the Civil Aeronautics Authority, the student received a civilian pilot's license. The program proved to be very successful, branching into primary and secondary courses. In 1942, because it was conducted in connection with the war effort, the name of the course was changed from Civilian Pilot Training to War Training Service. It was discontinued in August, 1943. At this time Conlon began research on the application of magnesium to aircraft structures. The department co-operated with the Dow Chemical Company in producing a wing Model SNJ-1 airplane for the Bureau of Aeronautics. This was the first magnesium aircraft structure to demonstrate a definite weight saving over the corresponding aluminum alloy structure.

In 1940 Associate Professor Thompson resigned to accept a position in charge of the aeronautical courses at the University of Texas. Arnold Martin Kuethe (Ripon '26, Ph.D. California Institute of Technology '33) succeeded him in 1941, and Franz Russell Steinbacher (New York '38e [Ae.E.], M. S. Michigan '42) was appointed Instructor. During World War II more changes occurred in the staff. Conlon, who had been promoted to

Associate Professor of Aeronautical Engineering was called to active duty with the United States Naval Aeronautical Reserve in 1942, and Stalker resigned to enter industry. Professor Kuethe became acting chairman, and Associate Professor Edgar James Lesher (Ohio State '37, M.S.E. Michigan '40), who had served on the staff in 1939-40, returned in the fall of 1942.

The department participated in the training of aircraft inspectors for the Army Air Force under the E.S.M.W.T. program from 1942 to 1944. Steinbacher taught an extension course, Airplane Structures, and Lesher taught one listed as Aerodynamics. Under the same program Kuethe gave a course in Dynamics of Compressible Fluids, and Jacque Houser (Alabama Polytechnic Institute '42e [Mech. Eng.], M.S.E. Michigan '44), Teaching Fellow in Aeronautics, taught courses in aircraft inspection.

In research, Kuethe supervised the construction of special equipment for the Wright Field Wind Tunnel at Dayton, Ohio. Airplane model tests were conducted for the Ford Motor Company and the Lee Wendt Company of Chicago; wind pressure and rain penetration tests were carried out for the Celotex Corporation of Chicago; and an investigation of the pressure distribution over a steel hut for Army use was completed for the Stran Steel Division of the Great Lakes Steel Corporation. Several confidential projects were undertaken for the Army Air Force in conjunction with the Engineering Research Institute.

In 1944-45 Steinbacher was granted a leave of absence to do work in structural research for the Douglas Aircraft Company. Lesher was also granted leave to work on special projects for the Stinson Division of the Consolidated Vultee Aircraft Corporation of Wayne, Michigan.

Julius David Schetzer ('39e, M.S. '44) was appointed Assistant Professor in 1944. In October, 1945, Conlon was released from duty as Commander with the United States Naval Reserve and returned to the University as Professor and chairman of the department. In the following year Professor Wilbur Clifton Nelson ('35e [Ae.E.], M.S.E. '37) and Associate Professor Myron Hiram Nichols (Oberlin '36, Ph.D. Massachusetts Institute of Technology '39) joined the staff. Lawrence Lee Rauch (Southern

California '41, Ph.D. Princeton '49) came to the staff as Assistant Professor in 1949. Hans Peter Liepman (Dipl. Ing. Swiss Institute of Technology '37, M.S. Harvard '39) was appointed Lecturer and given charge of the supersonic wind tunnel at Willow Run. While Conlon was on leave of absence in 1950 he served as Technical Director of the Air Force project (Arnold Engineering Development Center) at Tullahoma, Tennessee, and Kuethe again served as acting chairman of the department.

During this period the visiting teachers in the department included: Professor David J. Peery, head of the Aeronautical Engineering Department at Pennsylvania State College, Professor K. D. Wood, chairman of the Department of Aeronautical Engineering at the University of Colorado, Sir Richard V.H. South-well, of the Imperial College of London, Professor F. R. Shanley, of the University of California, and Dr. Leslie S. G. Kovasznay, Johns Hopkins University. In 1951, preparatory to a revision of the curriculum in aeronautical engineering, Associate Professor Schetzer visited various aircraft companies to study their needs. He obtained valuable information on dynamics of the airplane at the Douglas Aircraft Company in Santa Monica, California, which he presented in a series of lectures to the Douglas engineers.

In 1953 the professorial staff included: E. W. Conlon, A. M. Kuethe, W. C. Nelson, M. H. Nichols, J. D. Schetzer, and L. L. Rauch; E. J. Lesher; John William Luecht ('42e [Ae.E.]) and Robert Milton Howe (California Institute of Technology '45, Oberlin '47, Ph.D. Massachusetts Institute of Technology '50).

More than thirty years after he had first kindled an interest in aviation at the University of Michigan, Professor Pawlowski retired in 1946 to live at Pau, France. Members of the department and all others who knew him experienced a feeling of great loss when news was received that he had died on February 17, 1951.

Much-needed space for the department was provided in 1946-47 when the addition to the East Engineering Building was built. The staff moved into its quarters in the new wing in November, 1947. Offices, two instrumentation laboratories, and several classrooms were on the first floor. The Aerodynamics, Design, Transportation, and Propulsion laboratories were on

the fourth floor, and the Structures Laboratory was in the basement of the new wing. The small supersonic wind tunnel was moved to the Aerodynamics Laboratory on the fourth floor, and a 120,000-pound Tinius Olsen testing machine was installed in the new Structures Laboratory. The subsonic wind tunnel was modernized and converted to a closed-throat type. A six-component two-parameter strain gage type of balance system was designed, built, and installed, and a new fan having eight adjustable blades was installed.

On January 24, 1947, the Regents accepted the deed to the Willow Run Airport and Army Air Base from the War Assets Administrator. In doing so the University planned to improve facilities for instruction and research in the field of aeronautics. It was also intended that so valuable a property should not be abandoned, but should be maintained for public airport purposes and future emergency. A plan was devised whereby landing field and hangar facilities were made available to the airlines through lease; the University retained space for a new and enlarged postwar program of aeronautical instruction and research.

The Department of Aeronautical Engineering, through the Department of Engineering Research, negotiated the contract, known as the Wizard Project, with the Air Materiel Command in April, 1946, for an engineering study of a defensive guided missile. Another project, initiated for the Signal Corps in 1946, involved the measurement of atmospheric temperatures up to forty miles' altitude and the determination of the relative amounts of helium, neon, argon, and nitrogen in the upper atmosphere. To house these projects and provide the necessary laboratory facilities, the Aeronautical Research Center was developed at Willow Run Airport. Hangar No. 1, Bay 1, and parts of Bay 2, were remodeled into offices, stock room, drafting rooms, machine shop, electronics laboratory, and a model shop. A laboratory for upper-atmosphere research was also installed; this project, however, was moved to the University campus in November, 1947.

The large supersonic wind tunnel in the Warm-up Hangar at the Aeronautical Research Center was completed and put into operation in 1948. Laboratories for photographic work,

turbulence, and propulsion were also constructed in the Warm-up Hangar. In Building 22 space was utilized for propulsion test equipment.

The department was relieved of its connection with Project Wizard in 1950, when the Engineering Research Institute became responsible for it; the Aeronautical Research Center became the Willow Run Research Center. The supersonic wind tunnel and most of the propulsion facilities at Willow Run were retained under the technical supervision of the department.

In addition to the various government contracts, research has been completed during recent years for such aircraft companies as Goodyear Aircraft, the Consolidated Vultee Aircraft, Bendix Aviation, Grumman Aircraft Engineering, and Boeing Airplane, and for such automotive concerns as Ford Motor, Studebaker, Kaiser-Frazer, and General Motors. Contracts have also been completed for the following companies: Palmer Bee, the Dow Chemical, Askania Regulator, the Pullman Standard, Outdoor Advertising, and the Stalker Development Company, which was founded by Edward A. Stalker, chairman of the department from 1930 to 1942.

Although enrollment in the department has fluctuated with the economic situation of the country and with the needs of industry it rose to an all-time high of 358 undergraduate and nineteen graduate students in 1940-41. During World War II, in 1943-44, there were only 181 undergraduates and six graduates, but the number increased to 270 undergraduates and seventy graduates in 1947-48. The tremendous increase in graduate students was due not only to the expansion of graduate courses and qualified staff but to the special post-graduate Pilotless Aircraft course for the specialized training of officers for the Air Force. This course, first offered in February, 1946, has been changed to the Guided Missiles Program for Air Force personnel, which covers two calendar years and one summer session.

In 1946-47, graduate courses in propulsion and instrumentation, particularly in guided missiles, were added to the curriculum and later expanded. Courses such as Advanced Experimental Aerodynamics, Dynamics of Perfect Fluids, Dynamics of Compressible Fluids, Dynamics of Viscous Fluids,

Nuclear Energy for Aircraft Propulsion, and Guidance of Pilotless Aircraft were introduced or expanded to cover new material. The nuclear energy course has been discontinued in favor of a more extensive nuclear engineering program in the College, directed by a committee under the chairmanship of Professor Rauch.

Each year the number of doctor's degrees awarded by the department has increased. Seven were granted in 1952. In 1948-49 the department attempted to standardize the requirements for the master's degree according to the student's option (aerodynamics, structures, propulsion, or design). Of the thirty hours required for the master's degree twenty were prescribed and the remaining ten were elective.

Early in 1951, at the request of the Air Force Institute of Technology, the guided missiles curriculum for Air Force officers was revised by Kuethe and Rauch to permit greater concentration of effort in the field of guidance and control. Professor Nichols was made director of the program upon his return to the department.

Members of the staff have been active in engineering associations, such as the Institute of the Aeronautical Sciences, The American Society for Engineering Education (formerly S.P.E.E.), The Aero Club of Michigan, and the Michigan Society for Professional Engineers. Several have served on the advisory or editorial boards of the Journal of the Aeronautical Sciences and the Applied Mechanics Reviews.

Books by members of the staff include Stalker's Principles of Flight (1931); Thompson's Fluid Mechanics (1937) (with Russell A. Dodge, Professor of Engineering Mechanics), Nelson's Airplane Propeller Principles (1944), and Kuethe and Schetzer's Foundations of Aerodynamics (1950).

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[2]

Aerospace Engineering (1975)

J. C. Mathes

The former Department of Aeronautical Engineering has grown dramatically, especially in graduate programs and associated research activity. After World War II the large enrollment of Air Force officers in guided missiles and astronautics graduate programs strengthened the courses in guidance and control, instrumentation, high-speed aerodynamics, and rocket engines. The breadth of research activity now includes research on the upper atmosphere through instrumentation of sounding rockets and satellites, experimental and theoretical research in gas dynamics, research in the areas of automatic control, computers, and communications systems, and in solid mechanics.

[3]

Aerospace Engineering (2015)

1914: The first program in aeronautics in the United States

Professor Herbert Sadler was not only the chair of Michigan's Department of Naval Architecture and Marine Engineering. He was also an aeronautics enthusiast. The great-grandnephew of England's first balloonist, Sadler went to Boston in 1911 to see aviation pioneers in flight. He returned to Ann Arbor full of a new fervor for flight, and he soon formed the University of Michigan Aero Club. Members of the Club built a small wind tunnel and a bi-plane. Advisors to the club received advice from Wilbur Wright himself. "If you will advise them to build a glider and to fly it," he advised, "do not let them build it too light."

That was the beginning of Michigan's embrace of flight. The next step came soon thereafter, when Sadler offered a teaching position to a young Polish student in mechanical engineering named Felix Pawlowski, who had taken the world's first aeronautics course, offered in 1909 by Lucien Marchis at the University of Paris. Emigrating to the U.S., Pawlowski was wooed by Sadler to come to Ann Arbor, where he accepted a position as a teaching assistant in mechanical engineering. The bait was Sadler's promise that, in time, Pawlowski could also teach a course in aeronautical engineering.

Two years after his arrival, Pawlowski invited Lucien Marchis

to Ann Arbor for a series of lectures. According to Thomas Adamson, professor emeritus of aerospace engineering at U-M, "the appearance of a world-famous authority on an American campus strengthened the increasing academic respectability of aeronautical engineering in this country."

A year later, Sadler helped to establish the first formal course in aeronautical engineering in America. It was to be taught by Pawlowski in the Department of Naval Architecture and Marine Engineering. With that step, Michigan Aerospace was born.

1914 -1955

Early curriculum

The early days of Michigan's aeronautical engineering program were characterized by a race to keep up with the rapid pace of advances in the air. Pawlowski's inaugural course was Theory of Aviation, which covered the basics of aerodynamics and flight mechanics. The following year, with Sadler himself taking part of the teaching load, more courses were added, including Theory and Design of Propellers, Theory and Design of Balloons and Dirigibles, Advanced Stability, and Design of Aeronautical Motors. With these courses, the Department established itself as not only the first but the most comprehensive aeronautical engineering program in North America.

In 1922, Edward Stalker, a graduate of the Michigan program (B.S.A.E. 1919, M.S.A.E. 1923), was welcomed back to the Department as a professor. Soon thereafter, an emphasis was placed on airplane performance. Undergraduates were now required to make a complete analysis of an airplane's performance and stability as part of their degree program.

Michigan's first wind tunnel

In 1924, Pawlowski went to Europe to study aerodynamics and wind tunnels. Upon his return he designed and built Michigan's first wind tunnel, to be used for tests and experiments. It was created with the assistance of $28,000 from the Daniel Guggenheim Fund for the Promotion of Aeronautics. The

tunnel's octagonal test section was eight feet across and open to the atmosphere. The flow velocity inside could reach 250 miles per hour. The tunnel was put to use both in research and in teaching. Pawlowski's Theory of Aviation course began covering the results of wind tunnel tests beginning in 1927.

Soon thereafter, in 1930, the University regents approved the establishment of an independent Department of Aeronautical Engineering. Stalker was appointed its first chair.

The jet revolution

Several new courses were added to the Michigan curriculum in the 1920s to match the rapid advance of aviation: Mathematical Theory of Wing Profiles, Air Transportation, Theory of Aviation, Mathematical Theory of Aerofoils and five courses designed for graduate students. According to John Anderson, curator of the Smithsonian's National Air and Space Museum, "The aeronautical engineering students at Michigan were studying the very latest state of the art almost as soon as it became available."

This curriculum yielded two of the program's most famous graduates during this time: Elsie MacGill (B.S.A.E. 1927) and Clarence "Kelly" Johnson (B.S.A.E. 1932, M.S.A.E. 1933). MacGill was known as "Queen of the Hurricanes" for her work on the Hawker Hurricane, a Canadian fighter plane that played a major role in World War II. Johnson, whose work in the Michigan wind tunnel ultimately yielded his famous and revolutionary twin-tail design, went on to be the first team leader of the Lockheed Skunk Works. He is widely considered one of the greatest and most prolific aircraft designers.

U-M continued to adapt and add to its courses to reflect changes in the aeronautical design revolution. Theory of Aviation introduced modern aerodynamic theory. Theoretical Aerodynamics and Advanced Theoretical Aerodynamics covered boundary-layer theory. Helicopters and Autogiros began the program's work in this area. Kelly Johnson's successful research in the wind tunnel became a point of pride.

The study of compressible flow began with the arrival in 1941 of Arnold Martin Kuethe, who headed the aerodynamics group

and taught an important course, Mechanics of Fluid Resistance. Kuethe and Julian Schetzer would later publish a book, *Foundations of Aerodynamics*, that was based on their lectures and research. This text would eventually gain worldwide use for the study of gas dynamics. Indeed, Kuethe's arrival came just in time for the next aeronautical revolution — the birth of jets.

From its beginnings, the program had always stressed the importance of propulsion, so it adapted quickly to the advent of jet propulsion. In 1946 the curriculum was revised and two courses were added: Aircraft Propulsion I and II. Two graduate courses in aerodynamics also were added: Dynamics of Viscous Fluids and Dynamics of Compressible Fluids, which explored modern laminar and turbulent boundary-layer theory, basic theories of turbulence, shock waves and the mechanics of high-speed flows. A year later, a course in *Fan and Duct Systems* was added. In 1949, Fundamentals of Aerodynamics became a required course.

Research Facilities and New Wind Tunnels

During World War II, the Ford Motor Company used Willow Run Airport near Ann Arbor to build and operate the largest production line for B-25 Liberator bombers. Following the war, Willow Run was sold to the University in 1947 for $1.00, with the promise to use the facility for research. A quick transaction later, the Michigan Aeronautical Research Center (MARC) at Willow Run was founded.

With this acquisition, the study of aerodynamics and propulsion skyrocketed, so to speak. With the help of funding from the U.S. Air Force, a large supersonic wind tunnel was built — one of the first and largest at any university. It had an 8×13" test section and could generate flow speeds of Mach 1.4, 1.9, 2.8, and 3.8. Much of the work at MARC was done by Kuethe, who had succeeded Edward Stalker as chair in 1942. (Kuethe would serve as chair from 1942-1945 and from 1950-1951. In 1943 he was appointed the Felix Pawlowski Professor of Aerodynamics.)

Hans P. Liepmann joined the faculty as director of the Wind Tunnel Aeronautical Research Center in 1949. This laboratory, on U-M's new North Campus, contained various wind tunnels

where generations of students, both undergraduate and graduate, performed experiments as part of their aerodynamics coursework or research projects. Edward Lesher, who had joined the faculty in 1942, used the wind tunnels to validate many of his designs and ideas for experimental airplanes, including Nomad and Teal, in the 1960s and '70s. Lesher would ultimately pilot the Teal to seven international records, which earned him worldwide fame.

The start of control systems

World War II introduced missiles and rocket technology to the world. The Department responded by developing the Instrumentation Engineering graduate program and by hiring Myron Nichols from Princeton in 1946. As a research fellow at Princeton, Nichols had contributed significantly to the development of telemetry systems and issues related to the development of the atomic bomb. When he arrived at the Michigan, his main research goal was to study the properties of the upper atmosphere. To this end, he established the High Altitude Research Laboratory at Willow Run, which ultimately led to the development of the Nike-Cajun sounding rocket that was used worldwide.

Nichols also created an informal research group, Research Techniques, which included scientists and engineers from MARC and other Michigan programs. This group, which investigated how analog computers could be used in science and engineering, established Michigan as a leader in analog computer development and aircraft simulation.

While Nichols was establishing his research at Michigan, a graduate program was emerging that would play directly into his interests — a two-year graduate program in pilotless aircraft intended for Air Force officers. In 1949, the program became the Guided Missiles Program; it included courses on the control and guidance of pilotless aircraft, telemetry, feedback control, flight dynamics, analog computer simulation and the theory of nonlinear systems. Nichols was involved from its beginning. He taught two courses in 1946, one on aeronautical instrumentation and measurements, the other on guided missiles.

Soon two new faculty members joined the guided missiles program to work on control systems — Lawrence Rauch (1949) and Robert Howe (1950), both of whom had worked with Nichols. This trio, joined by other professors, eventually persuaded U-M's Rackham School of Graduate Studies to create a graduate program in instrumentation engineering, which Rauch would later lead. In 1952, M.S.E. and Ph.D. degrees in the field were inaugurated. Soon more faculty were hired: Donald Greenwood (1956), brothers Edward and Elmer Gilbert (1957) and Frederick Beutler (1957).

By 1955, the Department was offering comprehensive undergraduate and graduate programs in aeronautical engineering and instrumentation engineering; conducting a broad range of research projects; and collaborating with the U.S. Air Force in programs to train U.S.A.F personnel.

1955-1989: The Space Age

The Soviet Union's launch of Sputnik in 1957 was humankind's first step into space. When the U.S. responded with its own space program and a race to reach the moon began, Michigan's College of Engineering became one of the key players in the nation's massive program of research and development. NASA funding to COE included, among many other grants, $1.75 million in funding in 1963 to build the Space Research Building on North Campus, a precursor of the Department's wholesale move from Central Campus to North Campus.

As the shift to space research intensified, the Department changed its name in 1964 — from Aeronautical Engineering to Aerospace Engineering.

From Ann Arbor to the moon

Air Force personnel had been studying at Michigan since the 1940s. Now, in the 1950s, Michigan launched two programs – one in pilotless aircraft, the other in guided missiles – at the request of the Air Force Institute of Technology. Graduates of these programs received master's degrees in both aeronautical and instrumentation engineering. Many Air Force officers trained in these programs went on to work in the space industry.

The most celebrated of those became NASA astronauts, including Edward White, the first American to walk in space; White's crew-mate on the space-walk flight, James McDivitt; Jack Lousma, a native of Grand Rapids and Ann Arbor; and the all-Michigan crew of Apollo 15: Alfred Worden, James Irwin and David Scott. During three days on the moon's surface, Scott and Irwin left a document establishing a moon-based chapter of the University of Michigan Alumni Association. Upon their return to Earth, the astronauts were welcomed with a parade down Ann Arbor's Main Street and presented with honorary doctorates before a crowd of 30,000 at Michigan Stadium.

Another astronaut, Karl Henize, earned a Ph.D. in astronomy from Michigan in 1954; after a long career in space science, he died in a scientific mission on Mount Everest in 1993.

Harm Buning, who joined Aeronautical Enginering in 1956 as an aerodynamics professor, taught orbital mechanics at the Johnson Space Center to the first two astronaut classes. His memory is honored by the Harm Buning Graduate Teaching Award and Scholarship fund.

Research in Gas Dynamics

Into the space age, Arnold Kuethe continued his fundamental work in supersonic and subsonic mixing, flow separation and turbulent flows. His turbulent flow research was aided by Mahinder Uberoi, who had come to the Department in 1953; and William Willmarth, who joined in 1958 and conducted many of the experiments. Willmarth's work on hot-wire anemometry in boundary layers was groundbreaking.

From the study of aerodynamics came research on the atmospheres of other planets and the study of fluids under magnetic and electric fields, headed mainly by Rudi Ong (1957), Richard Phillips (1961) and Paul Hays (1964), who later became chair of the new Department of Atmospheric and Oceanographic Studies.

U-M engineers made advances in propulsion during this era, many of them at MARC at Willow Run. Most of MARC's research in this period dealt with problems in combustion and detonation waves. The facility was then headed by Richard

Morrison, whose primary research interest was unsteady flows. Later he became interested in rockets as well, conducting a good deal of research at Cape Canaveral.

Eventually, the Willow Run facilities moved to Michigan's North Campus and were renamed the Gas Dynamics Laboratory. Other researchers there included Roger Glass, Robert Cullen and James Nicholls. Glass eventually became associate head of the laboratory, studying screen combustion, detonation waves, supersonic ramjets and hypersonic wind tunnel testing and design. Nicholls, who earned his Ph.D. and became a professor in the Department, studied flows in shock tubes and detonation tubes; he was the first to create a standing or stationary detonation wave, which earned him worldwide accolades. He became head of the Laboratory in 1966.

Pauline Sherman, hired in 1956, was the first woman faculty member in the College of Engineering and the Department of Aeronautical Engineering. She directed the design and construction of the hypersonic wind tunnel.

Jet and rocket propulsion research was conducted throughout the 1950s and '60s, thanks to Thomas Adamson (hired in 1954), Martin Sichel (1961) and Arthur Messiter (1962). Adamson taught courses in fluid mechanics and jet and rocket propulsion and served as Department chair from 1983 to 1991.

Other faculty included Donald Geister, who began work in the Propulsion Laboratory as a research scientist in 1963 and taught laboratory courses until 2015, James Driscoll (1974), who studied hypersonic vehicles, combustion in gas turbine engines, scramjets and turbulent combustion.

As chair, Adamson hired several professors who steered the Department in new research directions. Luis Bernal (1984) studied fluid physics, focusing on turbulent flows. Gerard Faeth joined the faculty in 1985 and became head of the Gas Dynamics Laboratories. At U-M Faeth continued his research on droplet combustion and interaction between droplets and turbulent flows. He was the first faculty member in the Department to become a member of the National Academy of Engineering and was editor-in-chief of the *AIAA Journal*. (To the sorrow of his family, friends, students and colleagues, Faeth died suddenly in 2005. He is honored annually by the Department's Faeth

Memorial Lecture.) In 1985, Werner Dahm joined the Department. He used his experimental and computational background to study turbulent flows and combustion, ultimately becoming head of the Laboratory for Turbulence and Combustion. A computational fluid dynamics group was formed during this period, with the hiring of a global leader in the field, Bram van Leer (1986) and Kenneth Powell (1987). Philip Roe, another luminary in the field, joined the group in 1990.

Developments in systems and controls: CICE and beyond

In 1960, the Instrumentation Engineering program was renamed Information and Control Engineering to reflect the nomenclature of the era; its leadership shifted from Rauch to Howe in 1963. The program continued to thrive and develop as control systems became even more prominent in the space age.

In 1961, William Root joined the Department. Root had authored a prominent textbook on statistical communication and information theory, and his name and the growing authority of other Information and Control Engineering professors — including N. Harris McClamroch (hired in 1967) and Tyrone Duncan (1968) – enhanced the Department's reputation in these fields.

In 1968, a new interdepartmental degree emerged — the program in Computer, Information, and Control Engineering (CICE), which involved faculty from Aerospace, Electrical, Industrial and Mechanical Engineering. Several Aerospace faculty were closely involved — Gilbert, Howe, Rauch and Root — and many other faculty taught courses in the program.

By 1982, CICE had flourished, boasting over 120 students and 43 affiliated faculty members. It was one of the first academic programs in the U.S. to offer a degree covering computing, information processing, communications and control.

The Aerospace Engineering faculty at Michigan continued to make great strides in control systems. Rauch, for example, earned several awards for his work on radio telemetry, telecommunications, and space communications, and he ultimately left the University in 1977 to become the chief technologist at NASA's Jet Propulsion Laboratory. Root received

awards for his research on detection theory, the characterization of communication channels, information theory and complex stochastic systems. Frederick Beutler made major contributions to sampling theory, statistical communications, functional analysis and systems theory and stochastic control.

Other new faculty also contributed to the Department's reputation for excellence. Nguyen Vinh joined the faculty in 1968 and established a research program on aerospace dynamics and control, authored several books on those topics and received multiple AIAA awards, including the Dirk Brouwer Award for Mechanics and Control of Flight. William Powers was an active researcher and professor from 1968 to 1980; he specialized in singular optimal control theory and optimal low thrust control of space trajectories. His work allowed him to make significant contributions to several NASA missions and automotive control. Richard Phillips did a great deal of work in computer graphics, distributed processing and computer-aided design.

During much of this period, Robert Howe served as chair of the Department. He continued his research on guidance and navigation, control and simulation and the use of analog and hybrid computers. Howe also served on the Air Force Scientific Advisory Board and was awarded the AIAA deFlorez Award for Flight Simulation in 1988.

François-Xavier Bagnoud

Aerospace Engineering was the first of the engineering departments to move to North Campus. By the 1980s, the Department's space — which would later become the Wilson Center, home of student project teams — was in a poor state.

"When I was chairman, the blocks would sometimes separate, and I could see outside the building through the cracks," Adamson recalled during the Department's centennial celebration.

The labs lacked air-conditioning and the roof was so poor that experiments had to be kept in protective casings to shield them from incoming rain. During one particularly strong storm, the roof was ripped off the chair's office and that of Martin Sichel.

Books drenched in the downpour were frozen and dried in the wind tunnel's vacuum chamber.

Fortunately for the Department, while its leaders were trying to find funds to pay for a new home, a young Swiss student was thoroughly enjoying his undergraduate experience. His name was François-Xavier Bagnoud.

In 1982, Bagnoud completed his undergraduate degree in Aerospace Engineering and joined his father at Air Glaciers, Switzerland's largest private Alpine rescue and mountain flying company. Deeply passionate about his profession, he became the youngest professional IFR pilot in Europe at age 23 and completed more than 300 operations in the Alps and in Paris. Then, in 1986, only four years after his graduation, François-Xavier died in a helicopter accident in the desert in Mali, Africa.

To honor his life and his passion for aerospace, the François-Xavier Bagnoud Foundation was formed by his mother, Countess Albina du Biosrouvray; his stepfather, Bruno Bagnoud; and close friends. The Foundation provided significant funding for a new building for the Department; a landscape sculpture by the famed architect, Maya Lin, "The Wave Field;" graduate fellowships; a named professorship; and a center for rotary and fixed-wing aircraft design. The foundation also established the François-Xavier Bagnoud Aerospace Prize — an award of $250,000 given four times and administered by the foundation and the Department.

In 1993, the faculty and staff moved into its new quarters, the François-Xavier Bagnoud Building.

1989-2014

As the Department neared its 100th birthday, it grew rapidly.

One new field of interest was electric propulsion, opened at U-M by Alec Gallimore, who was hired in 1992. He established a lab by rebuilding a vacuum chamber that was obtained from the Bendix Corporation, where it had been used in work for the Apollo program. It was the largest university-based vacuum chamber in the country. Gallimore's lab conducted research on the thruster on the ongoing NASA Dawn mission, which orbited two dwarf planets in the asteroid belt.

Iain Boyd joined the faculty in 1999. His work centered on the simulation of aerospace systems involving nonequilibrium gas and plasma dynamics.

The two research groups –Gallimore's experimental work and Boyd's simulation-based work – combined to give Michigan Aerospace a commanding presence in advanced propulsion research.

With help from the FXB Foundation, research in vertical flight was augmented by the coming of Peretz Friedmann (1999), then of Carlos Cesnik (2001) .

Wei Shyy, who joined the Department as chair in 2005, further developed Michigan's reputation in computational fluid dynamics. During his term as chair, the Department improved the age and gender distribution of the faculty and the diversity of research interests. Faculty hired during this period included Matthias Ihme and Veera Sundararaghavan (2007); James Cutler and Krzysztof Fidkowski (2008); Ella Atkins and Anouck Girard (2006); Joaquim R.R.A. Martins and Ilya V. Kolmanovsky (2009); and Nakhiah C. Goulbourne (2010). Mirko Gamba (2012) joined the faculty while Ken Powell served as interim chairman.

A number of these faculty worked in fields already represented in the Department: Ihme and Fidkowsky in computational fluid dynamics; Sundararaghavan and Goulbourne in structures and materials; Kolmanovsky in dynamics and control. Others brought the Department into new disciplines. Cutler, with his interest in nanosatellite missions, developed the first NSF university-based satellite program. Martins, with his interest in multidisciplinary optimization, greatly enhanced the Department's involvement with aircraft design. Gamba, with his interest in experiments and diagnostics for combustion and reacting flows, extended the Department's research in hypersonic speeds.

Atkins and Girard brought the Department into research on unmanned aerial vehicles (UAVs). Atkins focused on integrating strategic and tactical planning and optimization algorithms to allow significant autonomous aircraft to fly safely even in the case of system failures and environmental uncertainties. Girard became the director of Michigan's Aerospace Robotics and Control Laboratory, where these cooperative control algorithms

were developed and tested on small and micro air vehicles and/or ground robots. She also served as principal investigator and director of the Michigan AFRL Collaborative Center in Control Sciences.

Several professors in control systems retired in this era.

Elmer Gilbert continued his research on optimization, linear and nonlinear systems and control synthesis until his retirement in 1994. Several major awards recognized his contributions: the IEEE Control Field Award, the Richard E. Bellman Control Heritage Award and election to the National Academy of Engineering.

Harris McClamroch added knowledge to nonlinear control of nonholonomic and under-actuation control systems and on geometric methods for multi-body dynamics and control problems. He served as chair of the department from 1992 to 1995, was elected President of the IEEE Control Systems Society in 1998 and retired in 2010 after a 43-year career at Michigan.

Pierre Kabamba, who joined the Michigan faculty in 1983, was extremely active in dynamics and robust control during his 31 years of service. His research interests were extensive, including optimal control, guidance, and navigation. When he died suddenly on September 20, 2014, his loss was keenly felt across the campus and beyond. His impact on students, alumni, staff and faculty is widely remembered and honored.

In 1991, Dennis Bernstein arrived at Michigan, bringing an extensive background in research on robust control. He created several successful research programs and served as editor of *IEEE Control Systems Magazine* from 2003 to 2011. His 2009 text, *Matrix Mathematics: Theory, Facts, and Formulas*, remains a widely-cited reference.

Also during this period, David Hyland joined the Department and created research programs in spacecraft systems, including adaptive imaging with spacecraft formations. (Hyland would serve as chair from 1996 to 2003.) He was a prominent researcher connected with both NASA and the Japanese Space Agency (JAXA) and made significant contributions to dynamics and the control of space vehicles near asteroids.

More recently, Ilya Kolmanovsky (hired in 2010), James Forbes (2013) and Dimitra Paganou (2014) joined the faculty to

continue developing research and courses on control systems. Kolmanovsky researched multiple topics from applications of control to aerospace and automotive systems. (Prior to his work at Michigan, Kolmanovsky worked with the Ford Motor Company's Research and Advanced Engineering division.) Kolmanovsky's early research was recognized when he earned the Donald Eckman Award as a young engineer in 2002.

Daniel Inman, an active researcher in the field of materials and structures, joined the Department as chair in 2011. He led the planning for the Department's centennial celebration.

As the Department celebrated its centennial year in 2014, Karthik Duraisamy (computational fluid dynamics), Venkat Raman (simulation of reacting flows), Henry Sodano (aerospace materials) and Dimitra Panagou (control of complex systems) joined the faculty.

Other significant faculty and alumni achievements of this period included the appointment of Werner Dahm as chief scientist of the Air Force in 2008 and the selection of Steve Chappell (B.S., Aero 1991) for the NEEMO 14 mission (NASA Extreme Environment Mission Opportunity). (In the NEEMO missions, groups of astronauts, engineers and scientists were to live underwater in Aquarius, an underwater research station, for up to three weeks at a time as an analog for living and working in space.)

During the late 20th and early 21st century, the Department grew in student research as well with the develop of student teams and a freshman course in blimp design. Started in 2005 and headed by Pete Washabaugh, ENGIN100-700 freshmen first-hand experience with aerospace engineering at the start of their college careers. During this one-semester course, student teams designed, built and flew helium-filled blimps through the atrium of the François-Xavier Bagnoud Building. Many of these students ultimately went on to become Aerospace Engineering majors and enjoyed successful careers after graduation.

The Department's partnership with NASA continued in 2006 with the Constellation University Institutes Program (CUIP). A five-year grant from CUIP allowed the University to carry out a cooperative project with NASA in four areas: Thrust Chamber Assembly, Propellant Storage and Delivery, Vehical Thermal

Structures and Re-entry Aerothermodynamics. Work on this grant was carried out by Professors Dahm, Driscoll, Gallimore, Shyy, Cesnik, Friedmann, Waas, Boyd, Powell and Roe.

Student project teams

Beyond Washabaugh's blimp course, aerospace students in this period conducted research and experiments in several groups, including the Michigan Aeronautical Student Association, M-Fly, the Michigan Exploration Laboratory and the Student Space Systems Fabrication Laboratory. These teams made their home in the Wilson Center, the former home of the Aerospace Engineering Department, after its renovation.

The Michigan Aeronautical Student Association, or MASA, aimed to increase student interest in model rocketry at Michigan by teaching them the basics and providing hands-on experience. Students with MASA designed, built and tested model rocketry in phases. Some competed in the annual Intercollegiate Rocket Engineering Competition.

The Michigan Exploration Laboratory (MXL), headed by James Cutler, brought together engineers of various disciplines to create an extreme comprehensive laboratory. Notably, MXL designed, built and launched several CubeSats — M-Cubed 1, M-Cubed 2, REX, GRIFEX and CADRE, which was launched on December 3rd, 2015, to the International Space Station. MXL also made achievements in high-altitude ballooning and hoped to launch a network of CubeSats, the Armada mission, in the coming years.

The Student Space Systems Fabrication Laboratory (S3FL) provided students with an opportunity for space systems design and fabrication outside the classroom. S3FL involved more than a hundred undergraduate and graduate students each year in various activities from nanosatellites to balloon payloads to microgravity experiments. (S3FL also collaborated with MXL on M-Cubed and RAX.)

On the opposite side of the aerospace spectrum was M-Fly, an aerospace design team of the Society of Automotive Engineers. Members participated regularly in the SAE Aero Design Competition, in which students designed, built and tested a

radio-controlled aircraft carrying cargo. M-Fly competed regularly in the basic category team and, in 2015, began competing in the advanced category team as well.

Aerospace's second century

In September 2014, the Aerospace Engineering Department marked its centennial year with a celebration of its history and a look forward. A gala was held to mark the anniversary at the Yankee Air Museum near Ann Arbor. The Department's influence was honored by a 15-airplane flyby at Michigan Stadium during Michigan-Utah football game. To commemorate a century of aeronautical and space engineering at Michigan, a block-"M" flag — put in place by Corey Brooker (B.S.E. 1994, M.S.E. 1995), lead systems integrator for Lockheed Martin — was launched on the Orion capsule test mission on December 5, 2014.

As the Department's second century began, its engineers and students continued to explore the unknown. A new hypersonic lab was being developed that would allow experimental aircraft to be tested at speeds up to Mach 13. This addition to the Gas Dynamics Imaging Lab, headed by Mirko Gamba, would allow Michigan research to focus on scramjet technology that could power the re-useable space rockets, drones and airplanes of the future. The lab, which can reach temperatures as high as 8,000 degrees Fahrenheit, was to be one of only a few facilities in the world that could sustain such high temperatures.

With the development of scramjets, UAVs, the commercial space industry and more, there could be no doubt that the students and faculty of Michigan Aerospace would meet the challenges of coming eras in flight and space exploration.