Paper offered to EUCASS 2013, 5th European Conference for Aeronautics & Space Sciences, Munich, Germany, 1-5 July 2013

21 January 2013

Abstract

Martin Summerfield and the first USA operational liquid rockets

Leonard H. Caveny[*]

Consultant, Fort Washington, Maryland 20744 USA

Overview

Martin Summerfield (1916-1996) pioneered in rocket propulsion and combustion research. In 1940, he began his propulsion career as a California Institute of Technology (Caltech) graduate student working for Theodore von Kármán (1881-1963) on the US Army Air Corps project to demonstrate the first US liquid-propellant rocket jet-assisted takeoff (JATO). The rocket units he designed were flight tested in 1942. The work was in conjunction with space exploration visions of Frank R. Malina (1912–1981), his lifelong friend and colleague. The facilities they initiated by 1945 became Caltech's Jet Propulsion Laboratory (JPL); Malina was its first director. From 1942 to 1945, as a founder of Aerojet Engineering Corporation, Summerfield led development of liquid-propellant propulsion systems. The Aerojet Project-X program powered the prototype Northrop flying wing MX-324 demonstrator using a pressurized RFNA/hydrocarbon pressurized liquid rocket, but he did not succeed with his pumped engine for the Northrop XP-79 flying wing interceptor. The JPL liquid propulsion contributions are described in the context of the propulsion accomplishments of Robert Goddard and the German teams led by Werner von Braun and Hellmuth Walter. From 1945 to 1949, as a manager at Caltech's Jet Propulsion Laboratory, he pursued liquid rocket technology for space exploration. Malina and Summerfield, in anticipated satellites and space exploration, implemented a program of propulsion demonstrations to achieve escape velocities. Anecdotes, photographs, and motion picture clips are included to illustrate how Professor Summerfield's early experiences gave him keen insights into practical problems, hardware, schedule, and budgets.

Themes to be developed in paper and presentation

This paper builds on and draws from the 2011 history of Martin Summerfield's life and career.[*] This paper (with an *exception*) focuses on his liquid rocket engine (LRE) technical contributions between 1940 and 1949. (Personalities are discussed in the 2011 paper.) After 1949, he became a professor at Princeton University and established his renowned solid-rocket propulsion and combustion laboratory. The *exception* will be to point out during the presentation the contributions made by several of Professor Summerfield's students and post-doctoral staff in the audience. The most authoritative overall window to the 1936 to 1960 environment of Martin Summerfield is *The Wind and Beyond:* the autobiography of Theodore von Kármán as completed by Lee Edson in 1967. That volume only touches on the many significant contributions of Summerfield and Malina.

While this paper centers on Martin Summerfield's 1940 to 1949 rocket propulsion contributions, endeavors involving Martin Summerfield are not monolithic. His early history and contributions are intrinsically intertwined with Theodore von Kármán and Frank Malina's visions, leadership, and contributions. Dozens of America aerospace leaders, early in their careers, stepped from their difficult Great Depression educations directly into World War 2 leadership positions and have valuable histories. Martin Summerfield and Frank R. Malina are among them.

Most people associate Summerfield with solid-propellant rocketry and will be surprised to find this paper deals with his 1940s successes with liquid-propellant rockets. By the time he left JPL in 1949, few in the US, other than the Werner von Braun team, had more hands-on experience and success in liquid-propellant propulsion than he had. The paper addresses the view that by 1945, the Malina and Summerfield rocket propulsion accomplishments far exceeded those of Robert H. Goddard, the American rocket pioneer.

In June 1940, after completing all requirements for his physics PhD, Summerfield began his career in rocket research and development. For most of the 1940s, he worked closely with Professor von Kármán, starting with the GALCIT JATO program for the Army Air Corps. (GALCIT is von Kármán's Guggenheim Aeronautical Laboratory, California Institute of Technology.) Summerfield was highly skilled in optics and spectroscopy. However, by assigning Summerfield responsibility for developing the liquid-propellant JATO system, von Kármán immediately thrust him into fluids,

[*] Fellow AIAA, Leonard Caveny joined Professor Summerfield staff in 1969 and interacted with him after Summerfield left Princeton University in 1978. L.Caveny@verizon.net

[*] Caveny, Leonard H., "Martin Summerfield and His Princeton University Propulsion and Combustion Laboratory. Presented at AIAA Propulsion Conference, August 2011, AIAA Paper 2011-5711, 70 pages.

chemical kinetics, and heat transfer design challenges, i.e., aerothermochemistry in von Kármán's vernacular. He never had a course from von Kármán. GALCIT soon learned the government officials would threaten cancellation when they were not satisfied with the progress or management. This programmatic technique was inherent to Summerfield's manner; he understood it. For the demonstration, the Army selected the newly operational twin-engine Douglas A-20a bomber, take-off mass up to 9000 kg. The JATO specification was for two units each delivering ~450 N for 25 seconds. The GALCIT liquid-propellants group addressed a much larger total impulse and system complexity than the solid rocket JATO demonstrated in August 1941. The paper details facility, propellant combustion, ignition, and instability problems Summerfield overcame to qualify his RFNA/aniline pressure feed liquid rocket. The Summerfield-led liquid-propellant JATO would enjoy success eight months after the solid-propellant success.

By 1940, many development programs were classified. Thus, the US knew little about the substantial developments in German rocketry leading to von Braun's pumped LOX/alcohol powered V-2 ballistic missile and Hellmuth Walter's pumped H_2O_2/hydrazine-hydrate-methanol-blend rockets that powered the Messerschmitt Me-163B *Komet* interceptor. Both were operational in 1944. As will be explained, the GALCIT team knew little about the specifics of Robert Goddard's progress. Hence, all through WW-2, "discoveries and innovations" in the US on classified technologies were often local and not advertised. By presenting in Europe the US liquid accomplishments, we anticipate learning more about similar and comparable 1930s and 1940s developments in Europe.

The Aerojet Engineering Corporation, now called Aerojet, was organized at the end of 1941 and formally incorporated on 19 March 1942 by von Kármán, Malina, Summerfield, and several others. Production of solid and liquid propellant JATO units was the public release reason for the company. The paper will discuss how under Summerfield's direction, Aerojet expeditiously refined the JATO units and achieved production capability. Importantly, the classified rocket propelled Northrop flying wing interceptor (Project x) was the primary reason the US Army Air Force funded the build up of Aerojet. Project X was the reason for recruiting an illustrious staff of future aerospace leaders. Achieving the pumped RFNA/hydrocarbon engine for the interceptor was the primary development activity. The innovations on Aerojet's Aerotojet/Centrojet liquid-propellant engines include a pump drive shaft rotated (8,000 to 10,000 rpm) by two canted rocket engines that also contribute axial thrust. The drive mechanism was akin to the ancient Hero steam-jet whirligig, but depended on unforgiving high-pressure seals for nitric acid.

The Northrop flying wing MX-324 prototype using an Aerojet pressure feed RFNA/hydrocarbon liquid rocket flew under power for 4.3 minutes and landed safely on July 1944. Aerojet did not succeed with the pumped engine for the larger Northrop XP-79 flying wing interceptor before its wartime requirement ended. The paper comments on the successes of Hellmuth Walter's pumped liquid rocket engine for the Messerschmitt Me-163B.

Aerojet gave Summerfield the full range of experiences, bad and good, i.e., the unrewarding experience of developing a pumped rocket propulsion system for an airplane and the satisfying experience of taking the JATO systems from start to routine operational use. During WW-2, JATO units were credited with enabling numerous takeoffs, including helping fly out hundreds of wounded personnel, and rescuing crews of aircraft disabled at sea, who without the help of JATO would have been lost. The post WW-2 sales of JATO units plummeted. The continued applications were often special situations, e.g., the 1948-49 Berlin Airlift.

Summerfield returned to JPL from Aerojet in the autumn of 1945 to take part in planning, research, and analysis of possible applications of rocket propulsion for space flight, as Chief of Rockets and Materials. After 1946, more of the reports had "long range," "high performance," or "escape velocity" in their titles. In 1946, the "Malina-Summerfield Criterion" for step-rockets was formulated. Also in 1946, Malina and Summerfield published their famous "Escape from Earth" paper;[†] 1946 and modern performance parameters are contrasted.

Malina aggressively pursued the development of the liquid-propellant rocket powered WAC-Corporal missile as a sounding rocket. This was consistent with his personal aspirations of developing vehicles capable of exploring space. Malina was the public advocate; Summerfield delved into quantifying the challenges.

In 1946, Summerfield suggested to Malina the concept of using JPL's WAC-Corporal as a second stage atop of one of the German V-2s brought to the US. The stack became known as the Bumper-WAC. From 1948 to 1950, a series of eight flight records were set, e.g., first US two-stage liquid rocket, achieved a US record altitude of 393 km, and the first US hypervelocity (~ Mach 7) vehicle.

The presentation will include three amusing short film clips of von Kármán, Malina, and Summerfield during several key GALCIT events.

[†] Malina, F. J. and Summerfield, M., "The Problem of Escape from the Earth by Rocket," JPL Publication No. 5, 23 August 1946; Malina, F. J. and Summerfield, M.; also, *Journal of the Aeronautical Sciences*, 1947, Vol. 14 No. 8, pp. 471-480.