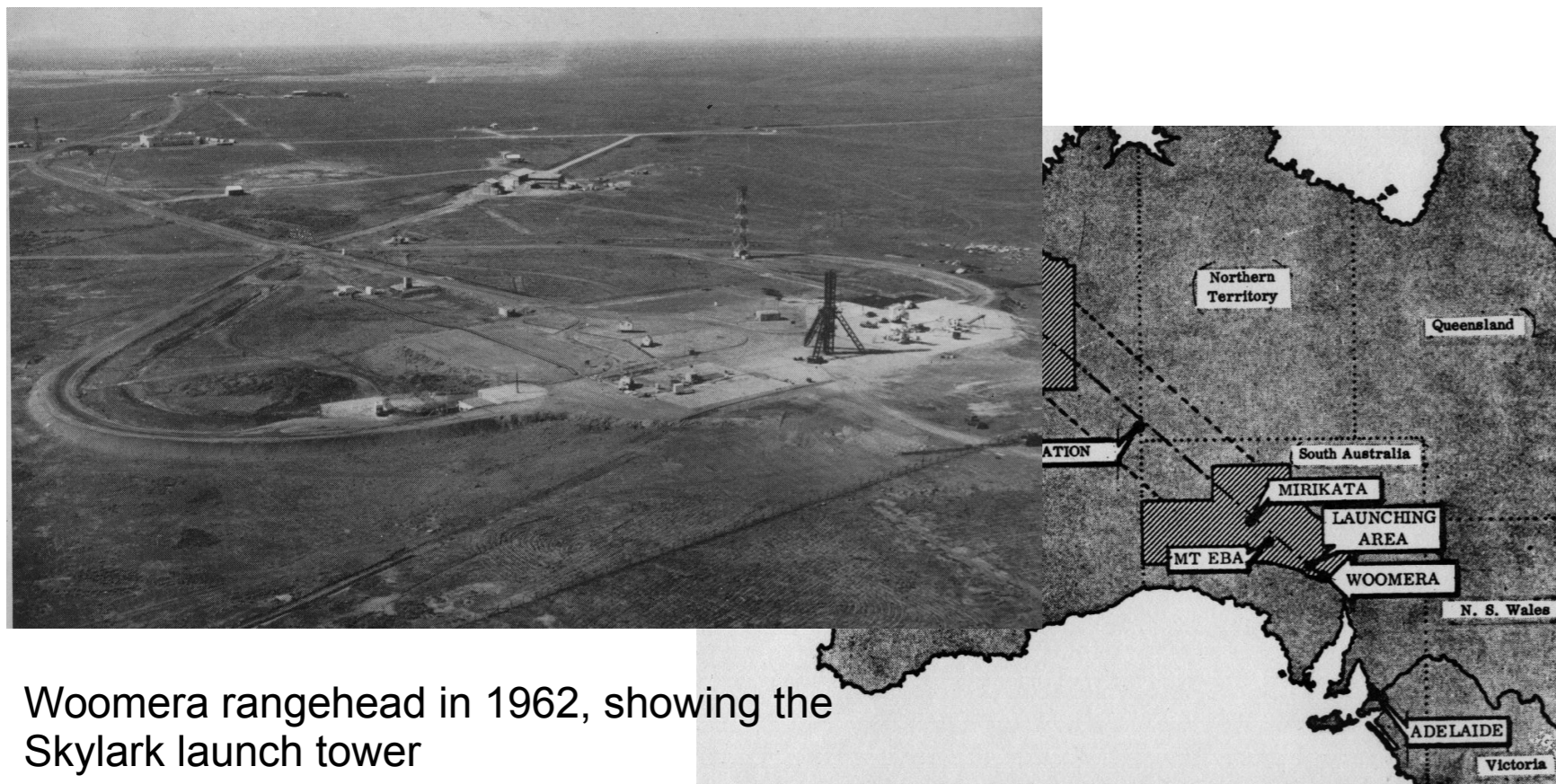


SUBORBITAL SPACE ASTRONOMY AT LEICESTER

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As part of a comprehensive inventory of rocket launches (<http://www.planet4589.org/space/lvdb>) I present a summary of the sounding rockets associated with the Leicester X-ray group. A full listing of Leicester flights can be found at <http://www.planet4589.org/space/misc/lux.html>.



Woomera rangehead in 1962, showing the Skylark launch tower

Early Days

The earliest days of the UK space effort were centered at UCL under Harrie Massey, and used Skylark rockets launched from the test range in Woomera, South Australia to study the upper atmosphere and ionosphere. The first Skylark was launched on 1957 Feb 13, 8 months before Sputnik.

On 1959 Jul 8, Skylark rocket SL14 soared into space carrying Ken Pounds' first experiment to measure the solar X-ray flux by measuring the blackening of filmemulsion recovered after the flight. Parachute failure wrecked the data on SL14, but SL12 in 1959 Sep was successful and reported in Pounds and Bowen 1962, MNRAS 123,347. By that time Ken had moved from UCL to Leicester and took the solar X-ray program with him. On 1960 Nov 23, SL49 was the first flight to carry a Leicester experiment. In those days several payloads shared a ride on the tiny Skylark, and SL49 also carried a UCL ionospheric experiment and an atmospheric experiment from University College Wales.

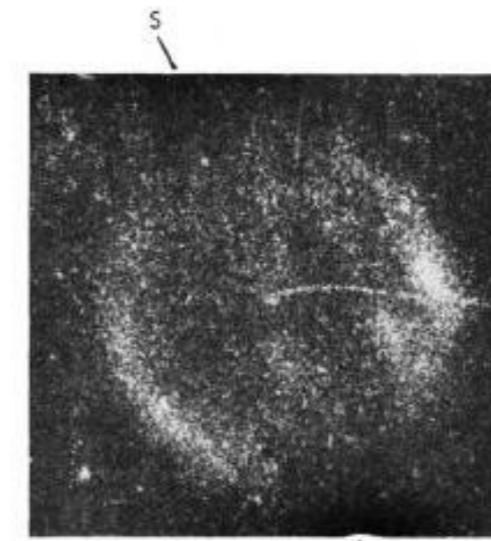
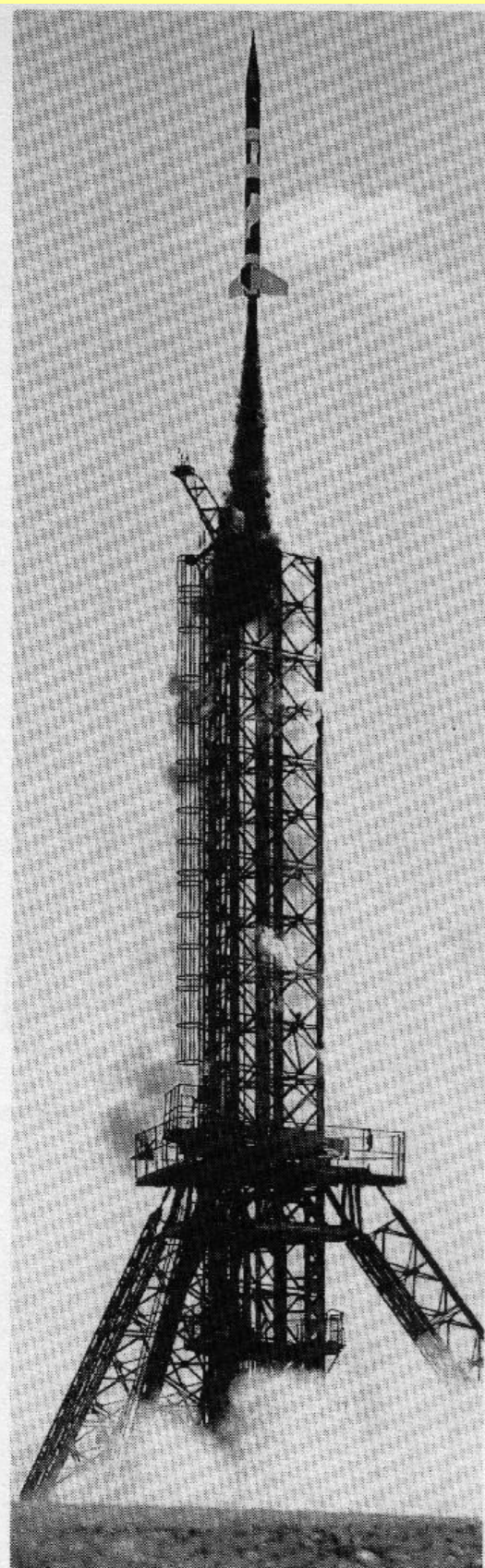


Fig. 1. Soft X-ray pinhole photograph of the Sun, 09:40 U.T., August 11, 1964. (The line running from the centre to the east limb is a scratch on the negative)

In 1964 attitude control was added to the Skylark, allowing real astronomical imaging starting with this pinhole camera 0.18-0.3 keV solar image taken on SL301 (P. Russell 1965, Nature 205, 684). SL304 in May 1966 flew an MSSL/Leicester Graz paraboloid telescope.

Australia, Sardinia and Spain

The advent of the European Space Research Organization (ESRO) in 1964 led to the opening of the Salto di Quirra range at Perdasdefogu, Sardinia, and the El Arenosillo range at Huelva in Spain. Seven Leicester Skylarks headed skyward from Sardinia, and one from Spain



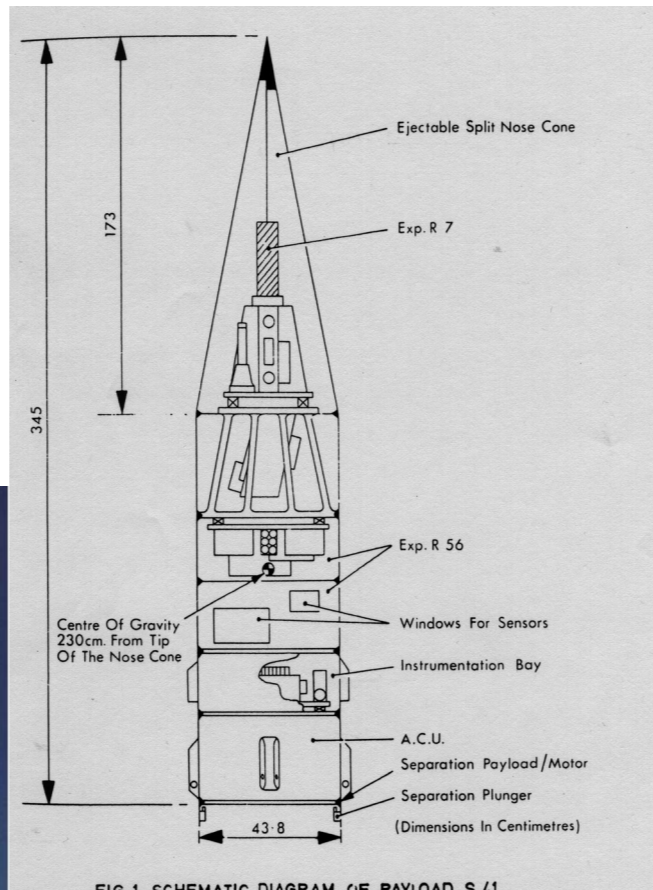
Launches from Woomera (left) and Sardinia (below)



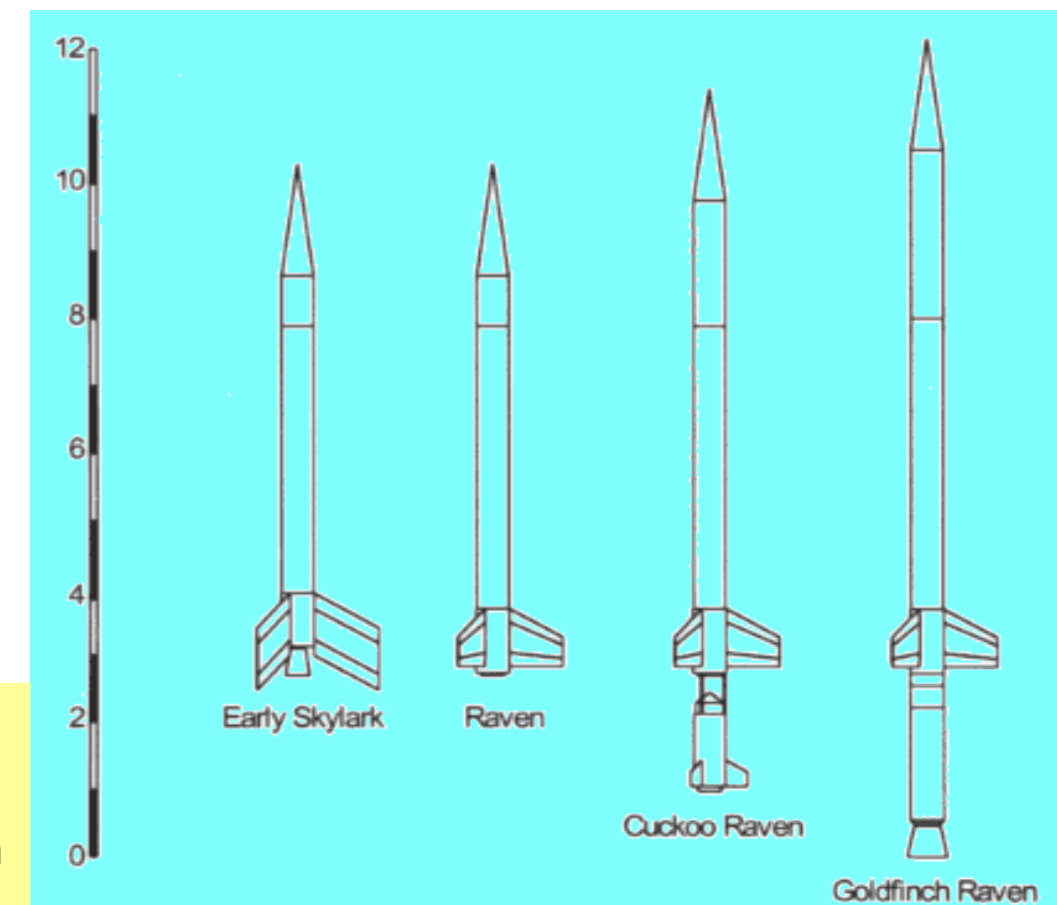
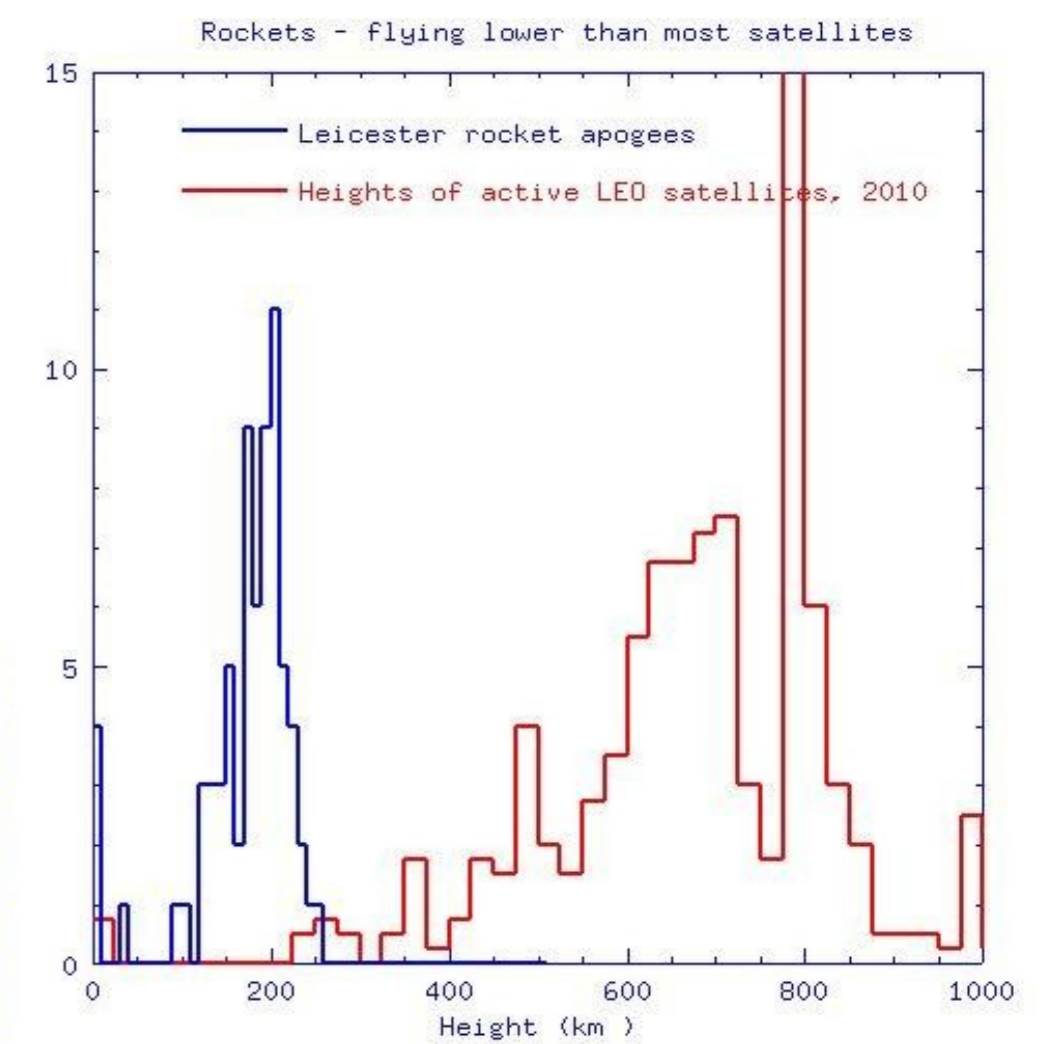
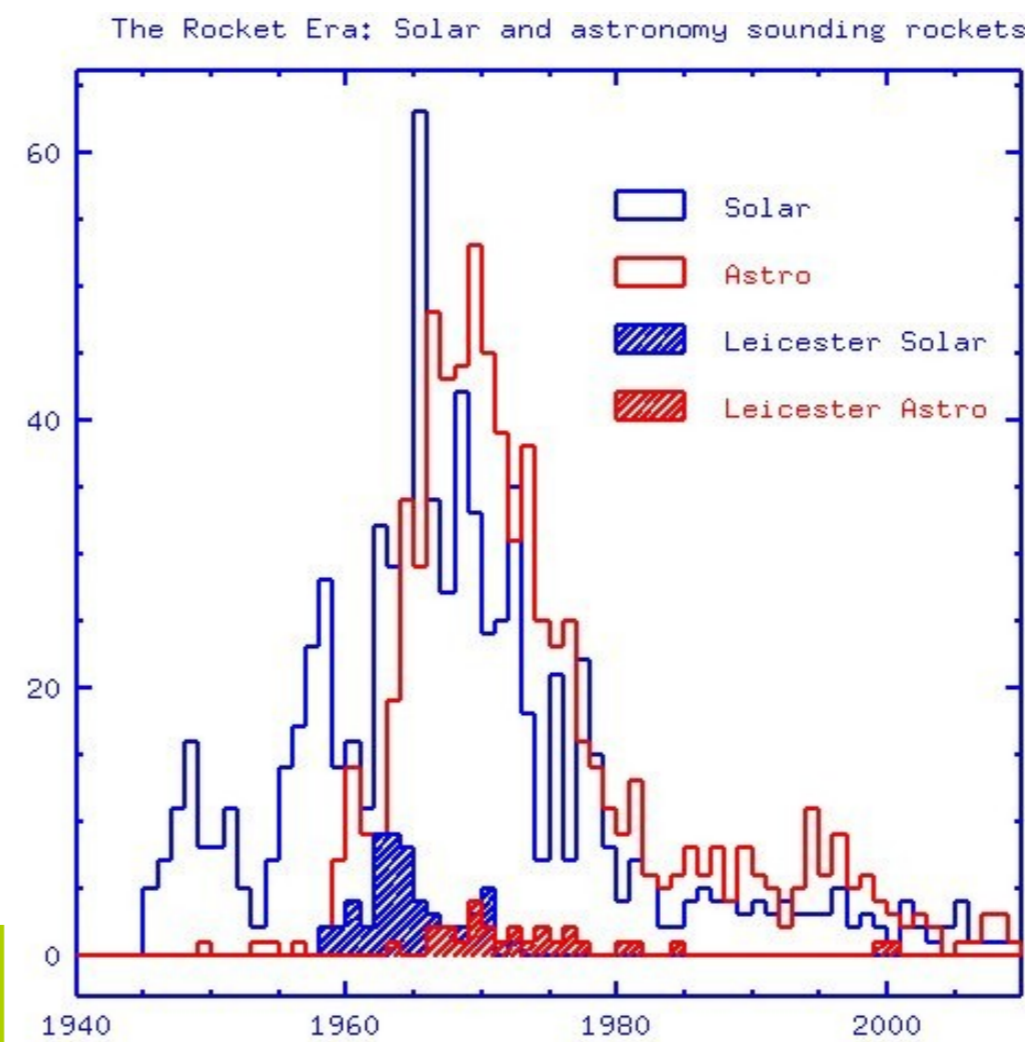
Right: SL1304 (photo lifted from 'Rocket Man' Roger Cooper), a Skylark 6 launched from El Arenosillo in Spain on 1974 Oct 7 in a joint Leicester-Tubingen-MPE project led by Jeff Hoffman and Rudiger Staubert (Staubert et al 1975, ApJ201, L15) to measure the X-ray extent of the Crab by lunar occultation

Sounding Rocketry

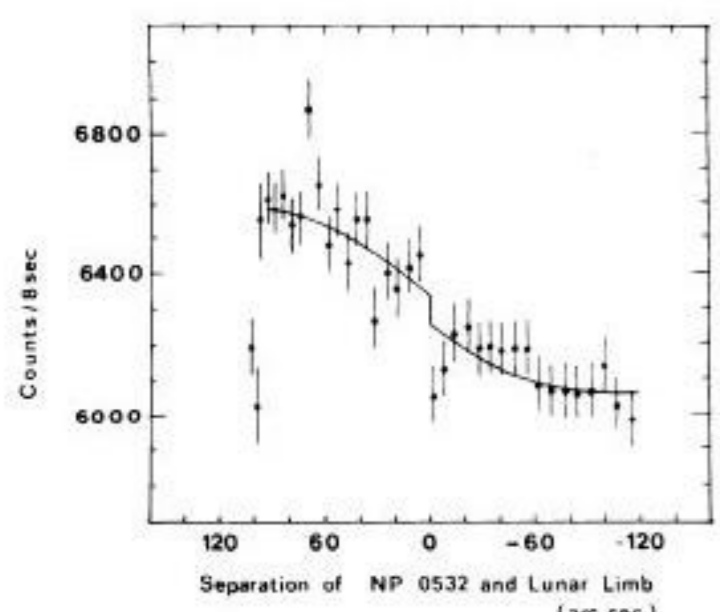
The first sounding rockets were captured German V-2 missiles flown by the US at White Sands in 1946 carrying ionospheric and solar UV experiments, but their big science impact came in the International Geophysical Year of 1957-58 when hundreds were launched. A sounding rocket flight is typically brief, with flight times of a few minutes, and reach altitudes of 100-300 km, below the region where most satellites orbit (see figure comparing Leicester rocket heights with all current satellites in low Earth orbit). Solar physics was an early role for rockets, with extrasolar astronomy lagging until the 1960s when accurate pointing became possible. With the increasing availability of satellite experiments in the mid 1970s, scientific rocket programs were scaled back although they still have a role, mainly for flight testing of new instruments. The total flights in my database (1945-2010) are: 770 solar, 733 astronomy, including 56 solar and 28 astro flights with significant Leicester participation.



ESRO S41 launched 1968 from Sardinia with R56 experiment from Leicester



Skylark (Raven 2)	Skylark (Raven 5-8)	Skylark 3	Skylark 6/7
6 flights 1959-61	34 flights 1961-71	21 flights 1965-72	10 flights 1970-76



0.15-1 keV Cyg Loop image from NASA Astrobee F flight 25.21UH, 1977 Jul 27 Rappaport et al 1979, ApJ227,285)

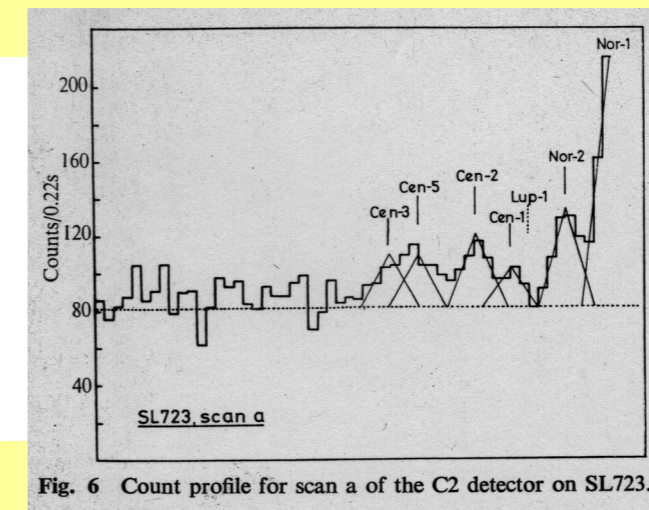
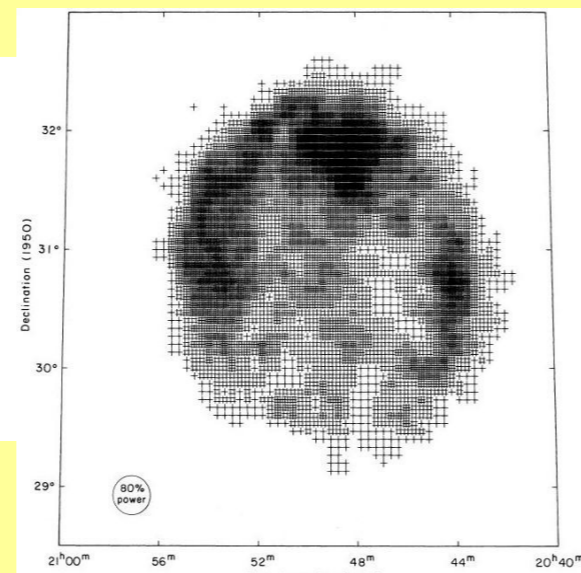


Fig. 6 Count profile for scan a of the C2 detector on SL723.



Black Brant IX with J-PEX credit: U Leicester

Nike Apache to Black Brant: other rocket types

A few other rockets were used, starting in 1963 Dec with a solar X-ray flux experiment which flew piggyback on a NASA Nike Apache ionospheric mission, NASA 14.37GI launched from White Sands in New Mexico, and a 1964 Apr flight on an Aerobee 150, NASA 4.113GA-GI, also from White Sands. Both of these flights were hit by rocket failures.

In 1965-66 Leicester teamed up with ESRO, the European Space Research Organization (an ancestor of today's ESA). It flew solar X-ray payloads on ESRO Centaure C06/1 from Salto di Quirra in Sardinia, and ESRO C06/2 from a temporary site at Karystos in Greece set up to study the 1966 solar eclipse.

In 1977-1985, a collaboration with the Massachusetts Institute of Technology led to soft wide-field Wolter I X-ray telescopes flying on NASA Astrobee F and Black Brant VC rockets from White Sands. The Black Brant VC was a distant Canadian relative of the Skylark, originating from the same mid-1950s British research. When given a US Navy surplus Terrier boost motor it became the Black Brant IX, which was used in 2000-2001 for two flights of the J-PEX ultraviolet spectrograph in collaboration with the Naval Research Lab in Washington, DC. J-PEX 2 was - so far - the last of the Leicester rockets.

Other players

Leicester was not the only group flying solar physics or astronomy rockets! Here are the other groups I know of:

- USA:** NRL, APL, AS&E, AFCRL, Goddard, SAO, Livermore, MIT, Princeton, Lockheed, Kitt Peak, Wisconsin, JHU, Columbia, Berkeley, Caltech, Colorado, Harvard, Calgary, Cornell, Montana, Michigan, Stanford, SWRI, USC, Penn State, Boston U
- UK:** UCL, MSSL, Birmingham, Jodrell, Southampton, Culham, ROE, RSR/S/RAL
- Others:** Bologna, Utrecht, MPE, Tubingen, Leiden, Bonn, Marseille, CNRS, Lebedev, ISRO, PRL-Amhedabad, Tokyo, Nagoya, KARI, Adelaide

Apologia

I am highly conscious of the cheekiness involved in telling you about your own history! My hope is that you'll correct my mistakes and help me improve the public historical record. Please send all comments to jcm@cfa.harvard.edu and feel free to shovel boxes of old flight documentation out of your garage into my bulging carry-ons.