# MAN-POWERED FLIGHT IN SOUTH EAST ASIA

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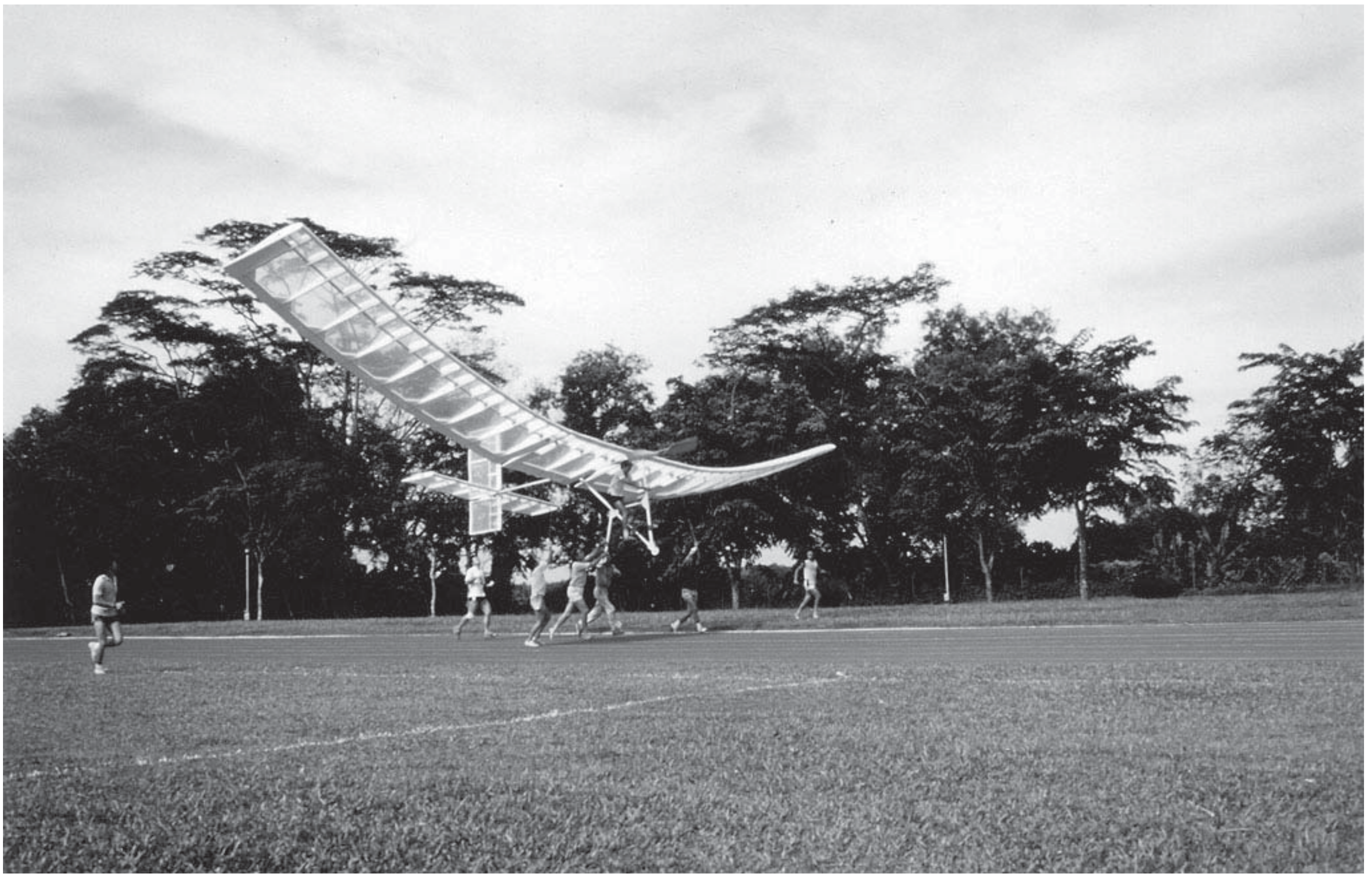
The authors both hold Professorships at the Nanyang Technical Institute in Singapore. Earlier In their careers they both graduated from the University College of Swansea with honours degrees in mechanical engineering. Their involvement in the 'Aslam' project stems from a common interest in the teaching of engineering design through creative projects.

Prior to working in Singapore R A Palmer was a lecturer at the University of Wales Institute of Science and Technology, in Cardiff, where he carried out research into mechanical drive systems. Keith Sherwin, MRAeS, was previously a lecturer at the University of Liverpool where he first became actively involved in man-powered `light through the 'liverpuffin' project. He subsequently published two books on the subject and is currently a member of the man-powered aircraft group committee.



Aslam flying.

The 'Aslam' man-powered aircraft project carried out by second year students of the School of Mechanical and Production Engineering at the Nanyang Technological Institute in Singapore was part of a number of 'in-house' training programmes during the academic years 1984 and 1985.

Genesis for this project started back in 1969 with the 'Liverpuflin' man-powered aircraft built by students at Liverpool University'. Liverpuffin was the result of a major creative design project of a design-build-test type. It was argued that there was no standard solution existing for a man-powered aircraft and that such a device could be built by students using simple hand tools.

Not withstanding the rapid development in man-powered flight since 1969, the arguments for using a man-powered aircraft as the basis for a student project are still valid today. This was reinforced by the large number of students available for such a project at the Nanyang Technological Institute.

The Institute was established in 1981 to provide engineering degree courses with an emphasis on engineering applications. Its aim is in produce engineering graduates. Who are practice orientated and can make a positive contribution to Singapore's industrial organisations.

During the third year of study all students have a six month period of industrial attachment. However to ensure that the necessary emphasis is placed on the early development of both practical and academic skills, all students have to participate in a ten week term of in-house training at the end of the second year of study. It is designed to enable each student to gain "hands-on" experience within the familiar surroundings of their academic environment and under the direct supervision of the academic staff at the Institute- Within such a programme a man-powered aircraft provided the ideal basis for a creative design-build-test project.

Students in mechanical and production engineering participated in five different in-house training modules, each of two weeks duration. Modules were organised under the following titles: Applied Mechanics, CNC Laboratory. Thermo-Fluids. Workshop and Creative Design. The design and construction of Aslam came under the Creative Design module.

**Organisation**

It was thought that the large student numbers available would make the designing and constructing of a man-powered aircraft a viable proposition with the time scale of the ten weeks available. The second year student population in 1984 was 202.

It was considered that group sizes of 4041 were too large for one project, so a decision was taken to build two man-powered aircraft. Consequently. The second year class was divided into two teams, each consisting of 101 students. The decision had the bonus of engendering friendly competition between the teams.

Each team was required to design, construct and test its own man-powered aircraft. It was inevitable that the achievements of the two teams would be different 2. As a result only the Aslam project is discussed here as being the most successful of the two man-powered aircraft.

The design and construction was the task of groups of 20/21 students working on the project within a given two week period. There were obvious disadvantages with such a system particularly lack of continuity, but with only four members of staff involved in the supervision it was considered to be the most workable that could be arranged.

The roles required of the staff members included coordination, advising, assessment and basic organisation. At the start of the project it was anticipated that specific times during the week would be set aside for supervisory tasks. In reality, with so many students and the many new problems arising from such a project, supervision tended to be a full-time activity.

With the Institute being new., no large workshop was available for the construction of the man-powered aircraft. Permission was given to use a corridor 6 m wide and approximately 50 m long situated on the third floor of the Auditorium building. This posed some interesting problems in logistics since large items. Such as the wings and fuselage, had to be carried into the circle area of the Auditorium, lowered by rope into the stalls and then carried out through the main entrance.

Permission was granted from the Director of Civil Aviation to fly a man-powered aircraft in Singapore provided the attempt was made at the Institute sports field. So the aircraft had to be transported from the Auditorium building to the sports field a distance of some 2 km by road. As there were no suitable storage facilities at the sports field, it meant that the aircraft had to be transported to and from the Auditorium for each flight attempt.

This posed unique problems in that the man-powered aircraft had to be capable of being broken down into units sufficiently small enough to be easily moved through the campus, yet sufficiently robust to be transported without damage.

**Aslam project 1984**

**Design**

The specification called for a compact type of man-powered aircraft that would be comparatively easy to design and construct. Compact in this context meant a single seat aircraft with a maximum wing span of 18 m. Apart from these constraints the design remained completely open ended.

Design of a man-powered aircraft represents a fascinating challenge due to the low power available. Less than 350 W. Power can be related to the mass of the aircraft and the wing area:

Power proportional $\text{mass}^{2/3}$ / wing $\text{area}^{1/2}$

so that design must provide a workable compromise between minimum mass compatible with maximum possible wing area.

The group studied previous man-powered alrcraft 3,4 Whilst utilising some features from earlier aircraft, namely the Lissaman 7769 aerofoil section developed for the "Gossamer Condor" and a similar wing construction to the 'Malliga aircraft', the final design was entirely their own.

During the first two weeks the students completed the design of Aslam. With their lack of aeronautical knowledge a simplistic approach was made to the aerodynamic design, the final configuration being chosen for ease of construction, with a constant chord being used for all aerodynamic surfaces, wing, elevator, fin and propeller.

Details of the Aslam are as follows:

| | |
|---|---|
| Configuration | High wing pod and boom fuselage |
| Wing; span | 18 m |
| Aspect ratio | 11 |
| Primary structure | Aluminium tubing |
| Secondary structure | Expanded polystyrene |
| Covering material | 12 micron polyester sheet |
| Aircraft mass | 49.5 kg |
| Flying mass | 105 kg |
| Flying velocity | 7.5 m/s |
| Power input | 300 watts |

**Construction**

During the next few weeks the students had to use their ingenuity to construct something that was well outside their previous experience. For example certain students developed specialist techniques such as how to mould polystyrene sheets into the leading edge of the wing. Using warm air from a hair dryer.

Throughout the project, the emphasis was on testing parts to ensure structural integrity. A wing test section was constructed and tested by mounting the unit on a lorry which was then driven at the appropriate flight speed. Useful feedback emerged from the test relating to buckling of structural members, including information on the second moment of area and slenderness ratio of the section.

Construction of the Aslam wing posed particular problems such as how to prevent distortion of the outer wing ribs and trailing edge under the tension loads induced by the covering material. The 12 micron polyester sheet was held in position by double-sided adhesive tape attached to the rib sections. The covering being finally tensioned by applying heat with a smoothing iron.

Care had to be exercised in solving the distortion problems; increasing the rigidity of the structure by adding too much material would result in increasing the weight by an excessive amount. In the event, attaching pieces of expanded polystyrene sheet between the outer wing rib and the adjacent inboard rib solved one problem. The buckling or distortion of the trailing edge was not excessive and accepted as having little detrimental effect on the aerodynamic performance of the wing.

The control system was made as simple as possible to reduce the control problems of the pilot. From past experience it was known that lateral control was unnecessary provided an adequate dihedral angle was maintained for the wing. It was decided to provide the required dihedral angle through the normal deflection of the outer wing sections. With the defined performance of the aircraft being in a straight line no rudder control was considered necessary. The only control required

Last minute adjustments - note deflection of wing under its own weight.

was elevator control, provided by an all moving tailplane.

Drive to the propeller was also designed to be as simple as possible utilising bicycle parts. Power input was by pedal crank and chain wheel through bicycle chain to an idler shaft and then from the idler shaft by means of a crossed chain to give the propeller shaft a rotational speed of 150 rpm.

With a distance of 1.4 m between the centre of the idler shaft and the centre of the propeller shaft, the use of a crossed chain to change direction through 90 degrees proved to be satisfactory. However, the loads on the chains proved to be greater than expected and the bracket holding the idler shaft had to be redesigned and built several times during the course of the project, in order to withstand the loads.

**Initial test trials**

By the end of the penultimate week of the training programme, Aslam was complete and transported to the sports field. The aircraft was broken down into three basic units. One unit comprised the fuselage. Centre 4.5 m span wing section and tat surfaces, this unit was wheeled to the sports field using the undercarriage. The two other units, port and starboard wing sections, each 6.75 m span was carried to the sports field.

It was the first time the aircraft could be dynamically tested with the lift loads on the wing. To check that the structure was sound the authors ran with the pilotless aircraft at speeds varying from zero to flying speed. As a result several of the rib alummium tube glued joints on the starboard wing failed. Investigation showed that the joints had been made incorrectly with a poor mix of epoxy resin pointing to the need for strict quality control on a project of this nature where the structural integrity is of vital importance.

Repairs required the first few days of the final week

and the only other time that the aircraft could be taken to the flying field was on the final Thursday of the project.

A runway of 6 mm thick plywood was laid out on the soccer field. Wind conditions were ideal with strength of force 2. During the takeoff run the aircraft accelerated until after 20 m the rear wheel lifted off the ground. If the pilot had then actuated the elevator control so that the tail came down the aircraft would have lifted off.

In the event, with the rear wheel off the ground, the angle of incidence of the wing v: as reduced, reducing lift from the wing and preventing takeoff. The aircraft ran to the end of the runway and the front wheel embedded itself in the soft ground of the soccer pitch causing the whole aircraft to overturn. What has since become known in man-powered aircraft terminology as a 'nose over'

The resulting damage could not be repaired in the time remaining to the project and had to await a resumption in 1985.

**Aslam development 1985**

The Aslam project continued during the in-house training programme in 1985 but as one of several projects within the School of Mechanical and Production Engineering. As a consequence the project ran for six weeks only, with a group of just eight students working on the aircraft during each two week period.

The size of group allowed for improved supervision than the much larger group of the previous year and ensured that each student had an effective role to play within the project. The opportunity was taken to build an entirely new wing and to increase the span to 18.5 m. Although the basic configuration was fixed the students could still use their ingenuity with relation to both the detail design and production techniques. For example the sheet polystyrene leading edge was changed from an open section to a D section, making for a much more rigid structure. Inevitably construction took far longer than anticipated so that it was not until the Monday of the sixth and final week of the project, that Aslam was fully assembled. The assembly showed up some snags that necessitated another day of modification to the trailing edge of the centre section of the wing.

Following modification the remainder of the week was spent awaiting suitable opportunities to carry out taxying flight trials. In the event, two afternoons were available and or, the first of these, following transportation of the aircraft and assembly. Initial taxiing trials were carried out using a 12 mm plywood runway laid out again on the soccer pitch.

In order to safeguard against structural damage, students were strategically placed around the aircraft during each trial, with four students acting as handlers along the wing and one student following the tail to prevent the aircraft performing a nose over. The authors ran along each side of the fuselage in order to give encouragement and instructions to the pilot, whilst also giving a welcome boost during the initial stage of each run.

The initial taxying trials proved that the main wing structure was successful and that the control worked well. Trouble was experienced, however, with the drive system due to vibration experienced whilst running along the plywood runway. The 12 mm plywood proved to be less adaptable to this purpose that the thinner plywood used the previous year. Nevertheless, the trials continued throughout the afternoon until the aircraft started to liftoff and eventually achieved a 'hop' of 7 m. Nearly 0.5 m above the ground.

For the final afternoon's trials permission was sought, and fortunately granted, to use the running track at the sports field as a runway In all nine trials were carried out during the course of the afternoon resulting in five successful frights, the best achieving a height of 1.4 m above the runway and a duration of 6 s, a still air distance of 37 m Since the pilot Leow Swee Heng had no previous flying experience, but was chosen for his low mass of 54 kg combined with athletic prowess, the setting of the elevator control had to be established on a trial-and-error basis by external observation of the behaviour of the aircraft.

**General observations**

Experience with Aslam reinforced the authors belief in the use of a major project of this type with undergraduates. The students learnt that the translation of any idea into engineering practice requires sound detail design and construction. In the particular case of a man-powered aircraft the need for a lightweight structure forces the student to use an innovative approach to solving structural weaknesses, as opposed to the time honoured engineering technique of just adding more and more material.

Comparing the Aslam with the earlier Liverpuffin project, since one of the authors has been involved in both, Aslam proved to be far more successful due to both the enthusiasm of the students and the environment at the Nanyang Technological Institute.

With the Liverpuffin a decision was taken to utilise parts from the crashed Puffin 2 aircraft, a decision taken in order to simplify and speed construction. In the event the students saw the utilisation of the Puffin 2 parts as placing a constraint on the design and as a result lost motivation. By comparison the students working on Aslam were enthusiastic about it throughout especially as it represented a pioneering activity with the ASIAN region.

The environment at the Nanyang Technological Institute has proved to be ideal for such a project. Apart from the occasional tropical downpour of rain the climate in Singapore is perfect for such a venture with consistent winds in the force 1-2 category. The choice of pilot was also made easy due to the large number of very fit young men and women all having a mass of 55 kg or below.

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