

SCIENCE MUSEUM

SIR GEORGE CAYLEY'S
AERONAUTICS
1796–1855

By

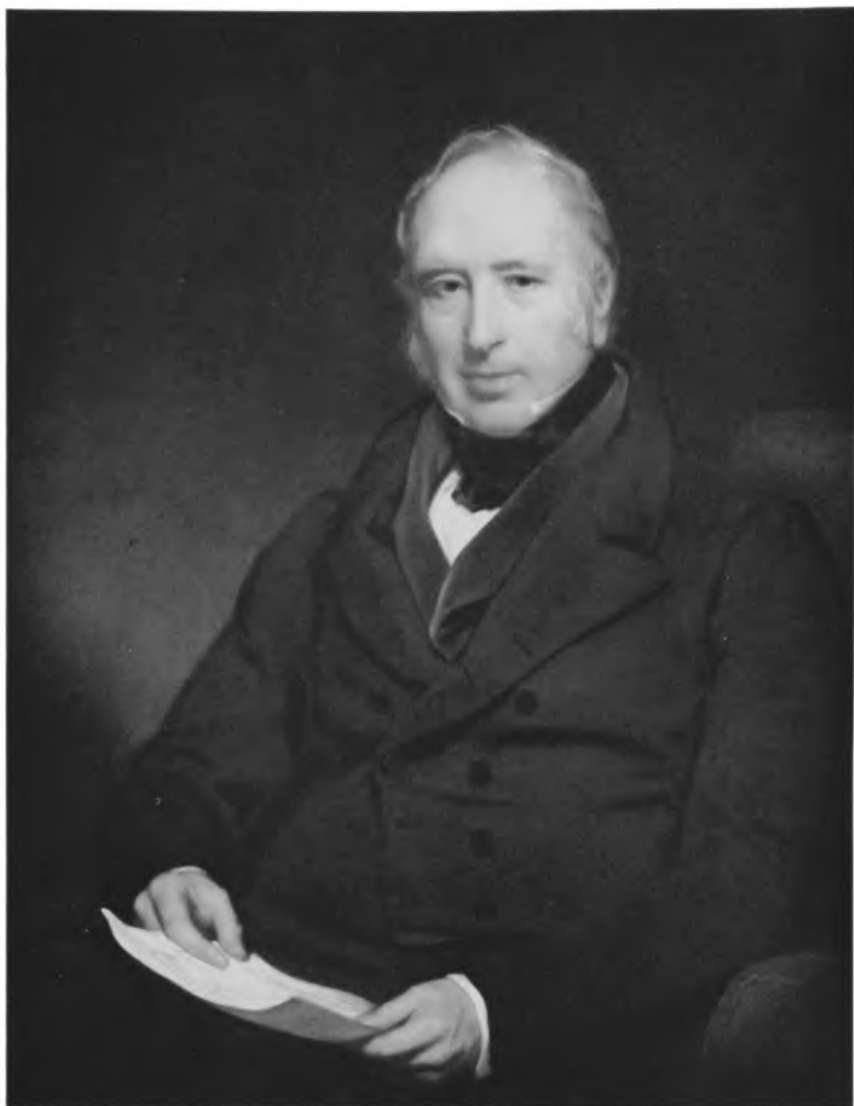
CHARLES H. GIBBS-SMITH

M.A., F.M.A., Companion R.Ae.S.

LONDON

HER MAJESTY'S STATIONERY OFFICE

1962



Sir George Cayley, Bart. (1773–1857). The portrait by Henry Perronet Briggs, R.A., exhibited at the Royal Academy in 1841. Formerly at Brompton Hall, now in the National Portrait Gallery.

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TO SIR KENELM AND LADY CAYLEY

You, to whom it may concern when I am gone,
may find the seeds of thought in these scrawls.

*A note inscribed by Cayley on the front
board cover of his early notebook*

Director's Foreword

Mr. Gibbs-Smith has already put the Science Museum in his debt by writing and presenting to it his scholarly historical survey "The Aeroplane", which takes the place of the now out-dated "Interpretive History of Flight" published in 1937, written by Mr. M. J. B. Davy when a Keeper in the Science Museum. He has now offered the results of his latest researches in the history of flight for publication by the Science Museum, and I have gratefully accepted this offer.

In this present study, working from both published and so far unpublished material, Mr. Gibbs-Smith goes deeply into the story of the development of Sir George Cayley's work in aeronautics, and collects together for the first time a detailed account of all his ideas, designs, models and full-size machines. The book is therefore a particularly appropriate addition to the Science Museum's publications, which, being based largely on its collections of objects of significance in the history of the development of science and engineering, are for the most part similarly concerned with the realisations of men's ideas.

D. H. FOLLETT
Director

International Tributes to Sir George Cayley

"No man living has bestowed more attention on the subjection of aerostation¹ than the philosophical baronet—pursued it through so long a course of years, and with so much zeal and perseverance; nor is there anyone who has brought to the consideration of it more science, or greater sagacity."

—*The Mechanics' Magazine* (England) 1843

"We therefore resolved to apply to you as the Father of Aerial Navigation."

—W. S. Henson (England) 1846

"C'est Cayley qui a véritablement fondé, dans la Grande Bretagne, l'école des aviateurs aujourd'hui très florissante."

—*L'Aéronaute* (France) 1877

"Le premier aéroplane conçu fut aussi 'complet' et tout avait été indiqué par son inventeur. Cet inventeur, ce précurseur incontestable de l'aviation, fut un Anglais, Sir George Cayley, . . . faut-il inscrire le nom de Sir George Cayley en lettres d'or au début de l'histoire de l'aéroplane."

—Alphonse Berget (France) 1909

"About 100 years ago an Englishman, Sir George Cayley, carried the science of flying to a point which it had never reached before and which it scarcely reached again during the last century."

—Wilbur Wright (U.S.A.) 1909

"England made the first substantial contribution to the science of aviation . . . Indeed, the contributions to the science of flight made by Sir George Cayley seem to be the most radical, fundamental and original of any that have been recorded up to the present time by the promoters of mechanical flight."

—A. F. Zahm (U.S.A.) 1913

"L'aéroplane est un 'invention' britannique: il a été conçu de toutes pièces par George Cayley, le grand ingénieur anglais qui a travaillé

¹Used here incorrectly for both lighter- and heavier-than-air flight.

dans la première moitié du siècle dernier. Le nom de Cayley est, même dans son pays, mal connu, et bien peu nombreux sont ceux qui savent l'œuvre de cet homme admirable, le plus grand génie de l'aviation. La lecture de ses travaux remplit l'esprit d'une admiration totale et pour l'esprit inventif de Cayley, et pour sa logique et son bon sens. Le grand ingénieur, en effet, a non seulement, sous le Premier Empire, entièrement inventé l'aéroplane tel qu'il existe actuellement, mais il a su comprendre que le problème de l'aviation devait être décomposé en études théoriques—Cayley a fait le premier des expériences d'aérodynamique pour l'aéronautique—et en études pratiques, tant pour le planeur que pour le groupe motopropulseur.”

—Charles Dollfus (France) 1923

“Sir George Cayley . . . the father of the successful navigation of the atmosphere by means heavier-than-air. It was he from whose amazing mind there sprang the definitive suggestion of a rigid-plane mechanism driven through the air by propellers connected to an efficient source of mechanical power.”

—F. A. Magoun and E. Hodgins (U.S.A.) 1931

“La plus haute figure technique, dans le premier tiers du XIXe siècle, est celle de Sir George Cayley, le véritable inventeur de l'aéroplane.

—Charles Dollfus and Henri Bouché (France) 1932

“I believe that it will be generally agreed the place of honour must be preserved for the great man who was at once the founder of aeronautical science as applied to mechanical flight, the inventor of the aeroplane, and a pioneer of the great airship.

—John Edmund Hodgson (England) 1936

“The principle of the airplane as we know it now, that of the rigid airplane, was first announced by Cayley.”

—Theodore von Kármán (U.S.A.) 1954

Preface

Sir George Cayley's work in aeronautics, although known in part to a few pioneers and historians during the last century and the beginning of this, was first brought to general notice by the researches of the late John E. Hodgson, who first embarked upon his researches at the suggestion of Charles Dollfus, the then Curator of the Paris Musée de l'Air. It is curious and not a little ironic to note that it was a Frenchman (Alphonse Berget) who in this century first recognised the true greatness of Cayley; and another Frenchman (Charles Dollfus) who initiated the train of research that has led to establishing Cayley as "le véritable inventeur de l'aéroplane".

It was in 1923 that Hodgson first lectured on Cayley, and in 1924 that he gave him a prominent place in his *History of Aeronautics in Great Britain*. In 1926 Hodgson was the first to examine the Cayley papers at the family seat, Brompton Hall (near Scarborough), when he also discovered the now famous early Notebook, which he published in full in 1933. It was also through Hodgson that the present Baronet, Sir Kenelm Cayley, most generously deposited the Cayley papers on permanent loan in the Library of the Royal Aeronautical Society.

It was Captain J. Laurence Pritchard, for many years Secretary of the Royal Aeronautical Society, who next took over the main Cayley research and recently, with the publication of his biography—*Sir George Cayley: the Inventor of the Aeroplane* (1961)—revealed for the first time Cayley's full stature as a scientist and as a man. Captain Pritchard devoted himself not only to Cayley's aeronautical achievements, but to the whole range of his other scientific and social activities: in addition he made a study of Cayley's friends and environment throughout his long life (1773–1857).

Having published his full-scale biography, Captain Pritchard kindly expressed the hope that the present writer would carry on, and undertake the next phase in Cayley research.

The subject of Sir George Cayley is of such great breadth and depth, that it might seem an unusually difficult task to select an appropriate subject of research; but in the present instance this was not so. It may seem curious, in view of the fact that it has been primarily Cayley's aeronautics which has attracted attention, that the subject of Cayley's aircraft, as such, has in fact been largely neglected.

Hodgson was primarily concerned with rediscovering and presenting Cayley in general terms as a great pioneer and as a great man: then—of incalculable value—he started making the sources available, and separating and noting the categories of manuscript material.

Captain Pritchard then took on the task of sifting the material, assessing it, and taking Cayley's true measure as one of history's last "universal" men: his chief aim has been to "see all round" Cayley, to get this new giant in perspective; and finally to present him to the public, and describe his manifold activities in the various branches of science and technology in which he excelled. That undertaking has now been splendidly accomplished in Captain Pritchard's biography of Cayley, the first biography of Cayley ever to appear. Captain Pritchard deals with the whole of Cayley's long and varied career, and of course covers his aeronautics: but this is dealt with from the standpoint of Cayley's general standing in aviation and aerostation, and his prophetic statements and suggestions. It was not Captain Pritchard's intention to deal with the types of aircraft as such, or their development.

In the few published papers concerning Cayley, and in the general histories of aeronautics, it is impossible to find more than half a dozen of his machines described and critically assessed, although many of them are included as accompanying but uncommented-upon illustrations; nor have any of the writers embarked on a study of Cayley's aeronautical development.

What I have therefore attempted in the present monograph is to suggest a chronology of every aircraft idea, design and realisation, that occurs in both the published and unpublished material; to describe the construction and operation of each machine; to relate each to Cayley's other ideas on the subject, and to outside influences if any; and to follow the trends and development of Cayley's aeronautical thinking from his helicopter model of 1796 to his last contribution in 1855.

As most of this research breaks new ground, I can only claim this as a tentative study; and I hope that other historians will follow to enlarge both on Cayley's aeronautical work dealt with here, and on the many other rewarding aspects of this great Englishman.

The Illustrations. There are over a hundred illustrations in this book in the form of line-blocks and half-tones. Many of these have not previously been published in book form. As the purpose of the illustrations is to illustrate Cayley's ideas and achievements, and not to produce—for their own sake—facsimiles of the original drawings, I have had to resort to various means of reproduction. The majority of Cayley's drawings and the accompanying words are impossible to reproduce satisfactorily from the originals, due to the fading of the ink, faintness of the pencil or pen lines, the colour or discolouration of the paper, or these various factors combined. Many of his published drawings, too, are difficult to reproduce owing to the fineness or lack of definition of the lines. I have sometimes therefore had to rely upon tracings, and even what I have called "clarified tracings"; the latter are tracings in which various lines and words which are fugitive or confused in the originals are strengthened or isolated to exhibit them clearly. When a

tracing has thus been "clarified", a note to that effect is included in the caption. Some idea of the difficulties involved in reproducing the drawings may be gained from what are shown in the half-tone plates.

The Quotations. Most of Cayley's published papers are difficult of access to the general reader, having appeared in periodicals of which there are now only a few copies available in libraries and learned institutions. In the bibliography I have indicated which papers have been reprinted. When it comes to the manuscripts, the position is naturally worse. I have therefore included in the present work a large number of quotations, both from the published and unpublished documents, in order to make available to the modern reader as much as possible of Cayley "in the original".

In the interests of aeronautical clarity, I have made certain minor adjustments of orthography when transcribing Cayley's writings. Cayley often showed little or no concern for punctuation, so a moderate number of marks have been included: his spelling has been modernised in such words as "publick" and "plain" (which he arbitrarily alternates with "plane", as noted in the Glossary); the terminal "or" has been extended to "our" in such words as "honour"; the curious sprinkling of capital letters has been reduced to lower case; and the frequently met ampersand has been written out as "and".

Acknowledgments. My thanks are due first to the Director of the Science Museum, Dr. D. H. Follett, and to the Keeper and Deputy Keeper of the Department of Aeronautics and Sailing Ships—Mr. W. T. O'Dea and Mr. G. W. B. Lacey—for their encouragement.

I am also deeply grateful to the present Baronet and Lady Cayley for their friendly interest and co-operation: were it not for their magnanimous decision to lend their family papers to the Royal Aeronautical Society, this work would have been impossible to undertake. My gratitude here has recently become even more profound, since Lady Cayley has lent me documents which we have never seen before, and which have proved to be as important as any that have survived (see Postscript to this Preface).

Those who are concerned with Cayley will always owe a great deal to Captain J. Laurence Pritchard, not only for the biographical work he has done, but for his active participation in all matters relating to Cayley: the present writer has for long enjoyed his friendship, advice and encouragement, and will always be deeply in his debt.

Another lasting debt of gratitude owing from all aeronautical historians—and the present writer in particular—is due to Mr. Frank H. Smith, Librarian of the Royal Aeronautical Society, and his assistant, Mrs. L. Kay. They have spared no trouble in helping the "Cayley cause", and many other aeronautical causes, and have constantly and philosophically borne my importunities over the years.

I would also like to offer sincere thanks to two other friends: to Mr. Peter W. Brooks—former Fleet Planning Manager of British European Airways—who combines modern technical expertise with a deep appreciation of historical aeronautics, and has generously read through my manuscript and given invaluable help; and also to Mr. J. L. Nayler—for thirty-six years Secretary of the Aeronautical Research Committee and Aeronautical Research Council—who has always taken a great interest in Cayley; not only has Mr. Nayler kindly read the proofs, but generously contributed to this book the comments of a modern aerodynamicist on the originator of his science a hundred and fifty years ago.

In research of the kind involved in this work, so much depends on the quality of the reproduction services available, since the day-to-day deciphering, tracing and marking cannot of course be done on the original manuscripts and early periodicals: in this connection I have been most expertly served, and am very grateful to those in charge of the photo-copying—to Mr. William Thomas Mason of the Public Record Office and his Staff, and to Miss Margaret Cooke of the Science Museum and her Staff.

CHARLES HARVARD GIBBS-SMITH
June 1961.

Royal Aero Club,
9 Fitzmaurice Place,
London, W.1.

SOURCES OF THE TRIBUTES TO CAYLEY

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DOLLFUS (C.): "Les Grands Précurseurs de l'Aviation—George Cayley, Alphonse Pénaud." In *L'Aéronautique*, 1923.²

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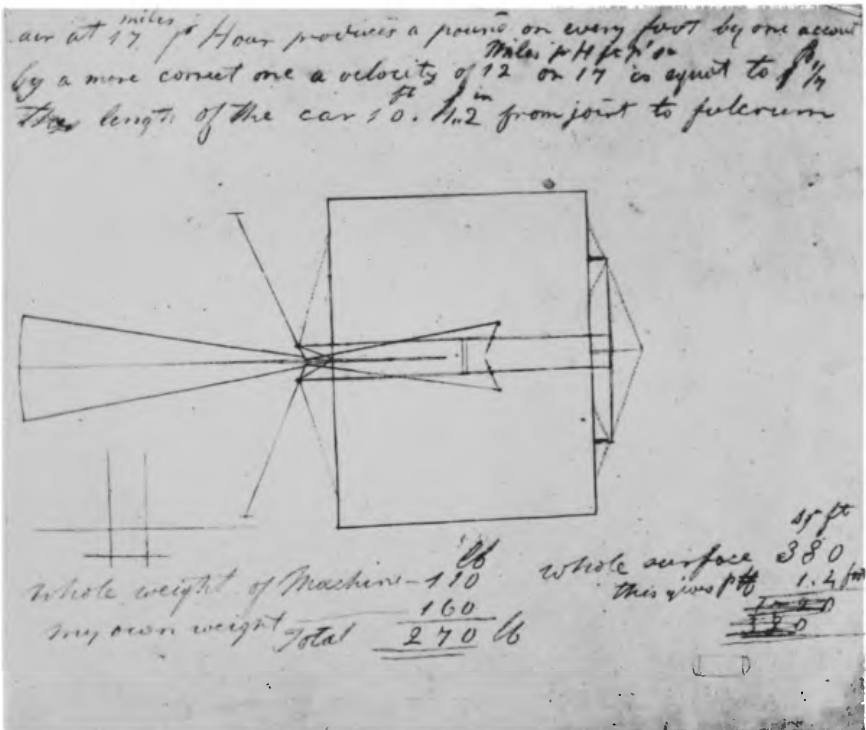
¹Alphonse Berget was then President of the Société Française de Navigation Aérienne.

²Charles Dollfus, former Curator of the Paris Musée de l'Air, is the premier aeronautical historian of France.

[Plate I]



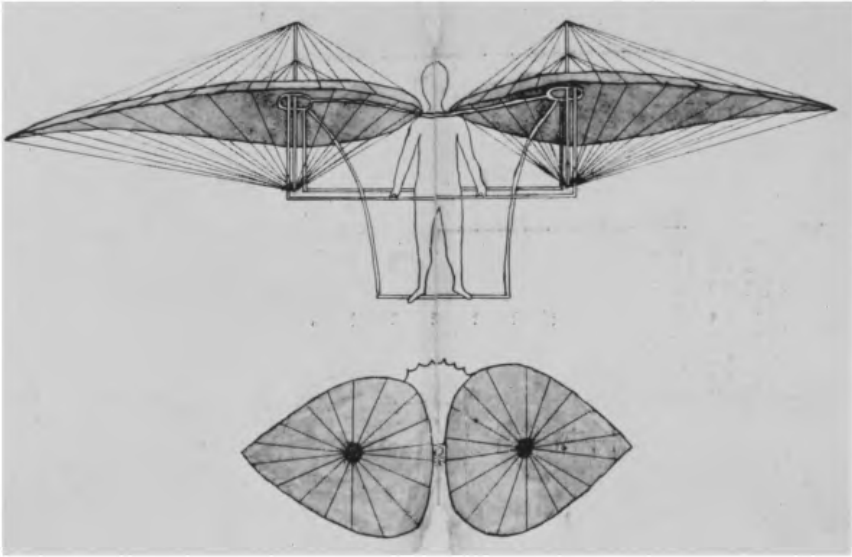
Silver disc (obverse and reverse) engraved by Cayley in 1799. Now in the Science Museum.



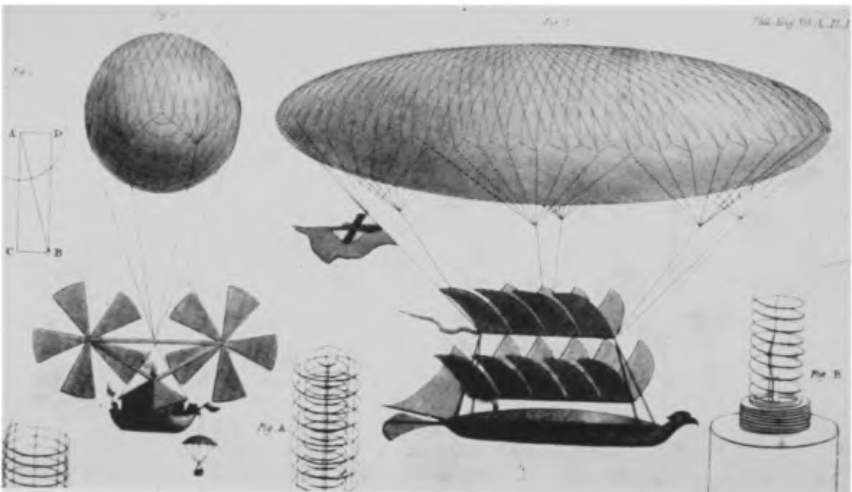
Finalised design for the full-size aeroplane of the silver disc type: c.1799.



Reconstruction, in the Science Museum, of the first model glider: 1804.



Sketch of Degen's flying machine sent to Cayley by Lord Mahon in 1810.



The third design for an airship: the original engraving, in Tilloch's *Philosophical Magazine*: 1817.

Postscript to the Preface

Just as this book was being completed and made ready for the press, yet another of those remarkable strokes of good fortune already noted elsewhere in the text, befell me—this time the most important of all. In clearing up loose ends, so to say, and trying to round off certain problems, I was recently in correspondence with Lady Cayley over the identities and activities of Cayley's two grandsons, both named George; in one of her letters to me Lady Cayley remarked that in going through the family papers to deal with my enquiries, she had noticed a number of items which related to Cayley's aeronautics, which might be duplicates of what we had among the papers in London, or of which we had copies: these items I realised, would be strewn through the more personal family papers which are not on loan to the Royal Aeronautical Society. Both Lady Cayley and I at first assumed that Hodgson had been through them in the 1920's and noted any items of aeronautical interest. But I was naturally—and acutely—interested in what these documents might be, for there are, in fact, very few notes among the loaned papers in London referring to material still remaining with the family. So Lady Cayley most generously lent me the group of manuscripts through which she had been searching. They arrived in my office on Thursday, June 29th, 1961, and never could a researcher have received such a miraculous windfall; and this, just as he thought he was ending his work. For among the material I received were four of Cayley's notebooks—till now unknown outside the family—three of them containing aeronautical entries; in one of them I found some of the most important single items in the whole range of Cayleyana—and indeed in the whole early history of aeronautics—his own sketches of the boy-carrying machine of 1849, and a table in his own hand of features both of that machine and of the famous "coachman-carrier" of 1853 (see Figs. 47-49). These entries and drawings, taken in connection with what is already available in the papers have radically altered the whole picture of Cayley's vital aeronautical work between 1848 and 1854. In addition there are beautifully executed drawings, and the only complete description, of his most successful model glider (of 1853), as well as drawings and descriptions of three more whirling arms, another gunpowder motor, and other important matters. Of non-aeronautical items there is also a great wealth.

What is referred to throughout the present work as the "Notebook" is the volume discovered at Brompton Hall by Hodgson, who edited and published it through the Newcomen Society in 1933. Of the four Cayley notebooks now lent to me by Lady Cayley, two are of concern to us at present. Cayley seems to have bought a number of similar

leather-bound books of this kind, and seems also to have planned to use them separately for philosophical or scientific subjects. With this presumably in view, he inscribed them in ink across their fore-edges; but he did not keep to whatever scheme he had in mind, and the two volumes in question—which range over a great variety of subjects—are inscribed respectively “PASSIONS” and “EGYPT”. These titles provide a convenient way of identifying the books, so I refer to the “Notebook” (that found by Hodgson); the “Passions” notebook; and the “Egypt” notebook.

As a result of this new material appearing, I have had to completely re-assess some of Cayley’s most important work, and therefore rewrite a number of sections, as well as insert new ones. Where the whirling arms, the gunpowder motor, and other non-specifically aircraft material is concerned, I have only had time to insert them in their correct sequence, and give brief descriptions: there is here a most fruitful field of research for aerodynamicists and engineers with historical leanings, and I hope that such workers will soon appear on the scene. Meanwhile, I can only offer my renewed thanks to Lady Cayley for her generosity, and consider myself the luckiest of historians.

C.H.G-S.

August 1961.

Contents and Illustrations

	<i>Page</i>
Director's Foreword	vii
International Tributes to Sir George Cayley	ix
Preface and Acknowledgments	xi
Postscript to the Preface	xv
1. <i>The First Helicopter Model: 1796</i>	I
Derived from a French device of 1784: described and dated, and illustrated in the 1809-10 paper (Fig. 1).	
2. <i>The Silver Disc Fixed-wing Design: 1799</i>	3
The first modern configuration aeroplane of history (Fig. 2 and Pl. I): also a description of a rotary engine.	
3. <i>The Full-size Silver Disc Design: c. 1799</i>	7
Undated designs closely related to the silver disc drawing (Figs. 3-5).	
4. <i>Early Ideas on Bird Propulsion: c. 1801</i>	11
Erroneous ideas on bird propulsion in the Notebook.	
5. <i>The First Paper on Aeronautics: 1804</i>	12
An unfinished paper, starting with a discussion of airships as a prelude to dealing with heavier-than-air flying.	
6. <i>The First Whirling Arm and the First Model Glider: 1804</i>	16
The first whirling arm in the service of aeronautics (Fig. 6) and the first recorded model glider (Fig. 7 and Pl. II); both also "firsts" in history.	
7. <i>Experiments with Finned Projectiles: 1804-05</i>	19
Described and illustrated in 1846 (Fig. 8).	
8. <i>The First Compound Design (fixed-wing-cum-flappers): 1805</i>	22
Designed before he understood bird propulsion technique: (Fig. 9).	
9. <i>The Aero Engine: 1807</i>	23
The first published account of the hot-air engine (1807): the description and illustration (Fig. 10) of the gunpowder engine (1807).	

	<i>Page</i>
10. <i>The First Oscillopter Design: c. 1808</i>	25
The first such suggestion in history (Fig. 11).	
11. <i>Camber and Aspect Ratio: 1808</i>	26
He shows by his description and illustrations (Figs. 12, 13) of the heron, that he is aware of the superior lifting capacity of the cambered wing, and of the high aspect ratio wing.	
12. <i>The First Ornithopter Design: 1808</i>	28
He turns momentarily to the pure flapping wing machine, without any fixed wings (Fig. 14): also designs an ingenious seat and working position for the pilot (Fig. 15).	
13. <i>The Aircraft Undercarriage: 1808.</i>	31
He invents the practical cycle-type tension wheel for aircraft undercarriages (Figs. 16, 17).	
14. <i>The Second (or partial biplane) Ornithopter Design: 1808</i>	34
He designs a second ornithopter, with a biplane counterpoise for compactness of construction (Fig. 18).	
15. <i>A Glider Model with Outer Wing Panels: 1808</i>	35
He makes and tests an experimental glider model (Fig. 19) and, for the first time in history, investigates the problem of the centre of pressure.	
16. <i>The Discovery of Bird Propulsion Technique; and the Improved Ornithopter Design: 1808</i>	37
He has now realised the true propeller action of a bird's wings, and designs an ornithopter accordingly (Fig. 20).	
17. <i>Tubular Beam Construction: 1808.</i>	39
He suggests tapering poles cut in half, hollowed out, and stuck together; also the use of bamboo for aircraft construction (Fig. 21).	
18. <i>The Sycamore Chat: 1808</i>	40
He discusses the autorotation of the sycamore chat as a relative of the helicopter (Fig. 22).	
19. <i>Streamlining (the solid of least resistance): 1809</i>	41
He designs a solid of least resistance, based on the shape of the trout (Fig. 23a); and another (undated) based on a dolphin (Fig. 23b).	

	<i>Page</i>
20. <i>The First Successful Full-size Glider (which is also the first tentative Man-Carrier): 1809</i>	42
He builds and flies (pilotless) the first full-size glider of history, which he also tests tentatively with a man on board.	
21. <i>Part I of the Paper "On Aerial Navigation", including the Second Oscillopter Design: 1809</i>	45
Inspired by erroneous reports of Degen's experiments (Pl. II), he writes the first part of his classic paper on aerodynamics, which includes discussions on aero-engines, fixed wing aerodynamics (Fig. 24), and his second design for an oscillopter (Fig. 25).	
22. <i>Parts II and III of the Paper "On Aerial Navigation", including the Dihedral Parachute: 1809-10</i>	51
He discusses parachutes (including the suggestion of the dihedral parachute) and makes a model (Fig. 26); the stability and control of fixed wing aeroplanes; ornithopters; flappers (Fig. 27); and streamlining.	
23. <i>Miscellanea: 1809-13</i>	58
He sketches (c. 1809) an ornithopter (Fig. 28); he and Lord Mahon correspond about Degen (1809-10); he writes to Culver (1910); makes notes on engines (1812); and notes for a steam-powered model (1813).	
24. <i>A Design for a Tandem Compound Machine: 1815.</i>	67
He describes and illustrates (Fig. 29) a compound machine with tandem fixed wings and tandem flappers, the latter providing much of the lift.	
25. <i>Flapper Testing: 1815-16(?)</i>	68
He describes testing full-size flappers, with an illustration (Fig. 30).	
26. <i>The First Paper on Airships; including the First Airship Design and Illustration: 1816</i>	70
His first publication on aeronautics since 1809; discusses Evans's inclined plane method of balloon propulsion; suggests a large elongated rigid twin-hull (side-by-side) airship (Fig. 31), inflated with hot air.	
27. <i>The Second Airship Paper; including the Second Design and Illustration: 1816.</i>	73
He now suggests a single hull type, hydrogen filled, and flapper propelled, using the woodcock's body as a basis for the hull-shape (Fig. 32).	

	<i>Page</i>
28. <i>The Third Airship Paper; including the Third Design and Illustration, and the First Propulsive Airscrew Suggestion: 1817</i> . . .	77
He receives a criticism of the flapper propulsion of his last design from John Evans, who suggests airscrews. Cayley considers this and suggests both flappers and airscrews on his new design (Pl. II and Fig. 33), which includes separate gas compartments.	
29. <i>Miscellanea: 1817</i>	82
He corresponds further with the former Lord Mahon (now Earl Stanhope); this is especially remarkable for his discussion of the moral background of flying and its possible use in war.	
30. <i>The Double-Kite Model Glider and a Suggested Man-Carrying Helicopter: 1818</i>	84
In a letter to Lord John Campbell he describes heavier-than-air flight, and describes and illustrates his double-kite glider model (Fig. 34): he also suggests a man-carrying helicopter.	
31. <i>The Second and Third Whirling Arms: 1818</i>	86
He returns to making tests with aerofoils on whirling arms, two new types of which he describes and illustrates (Figs. 35, 36).	
32. <i>The Goatsbeard Parachute Idea: 1829</i>	88
He studies the Goatsbeard fruit, and suggests a parachute based on it (Figs. 37 and 38).	
33. <i>Notes for a Proposed Powered Model: 1836</i>	91
It cannot be determined what type of model, or motor, he refers to here.	
34. <i>The Fourth Paper on Airships; including Suggestions for Directing Balloons; and the Second published Suggestion of Airscrews: 1837</i>	92
He suggests an improved method of propelling balloons by means of an inclined plane (Fig. 39); returns to airships and suggests a specification of one; he also suggests tandem (and swivelling) air-screw propulsion (Fig. 40).	
35. <i>Miscellanea: 1839-40</i>	100
A passing idea for an aeroplane or kite sketched (Fig. 41) without description, that harks back to the hexagonal kite of 1808; Cayley's portrait by Briggs; his attempt to found The Royal Aerostatic Institution.	
36. <i>Robert Taylor's Design for a Convertiplane: 1842</i>	102
The son of a friend sends him for criticism a highly original design for a convertiplane (Fig. 42); he replies and pretends he had thought of it himself; Taylor disappears from the scene.	

	<i>Page</i>
37. <i>The Publication of Henson's Design for his "Aerial Steam Carriage"; and Cayley's Retrospective Paper: 1843</i>	109
Henson's design is published (Pl. III); the <i>Mechanics' Magazine</i> praises it and also plays it down in favour of Cayley's work; he contributes a retrospective paper on aviation.	
38. <i>Cayley's Criticism of Henson; his Advocacy of the Airship; and his Design for a Convertiplane: 1843</i>	113
He criticises Henson's design; again advocates the airship; and then presents his own convertiplane design (Fig. 43), which is seen to purloin and exploit Taylor's basic ideas.	
39. <i>The Henson-Cayley Correspondence: 1846</i>	121
Henson writes to Cayley, seeking financial help: Cayley replies sympathetically but cautiously; Henson does not respond.	
40. <i>The Main Trends of Activity: c. 1848-54</i>	123
A summary of the directions his work takes from now on.	
41. <i>The Start of a New Phase in Design and Propulsion: 1848 (?)</i>	124
He draws a new type of compound machine (Fig. 44); a new type of flapper (Fig. 45); and a new transmission (Fig. 46).	
42. <i>The Boy-Carrying Machine (the "old flyer"): 1849</i>	127
He describes how a boy was airborne for some yards in a full-size machine, which he illustrates (Figs. 47-49); two undated letters possibly referring to this machine are also discussed here (Fig. 50).	
43. <i>The Model Glider with Riding Rudder: 1849</i>	138
He describes and illustrates (Fig. 51) a new, sophisticated and successful model glider, with the rudder mounted on the elevator.	
44. <i>A Model Test-Rig of Gunpowder Motor and Flappers: 1850</i>	140
He describes and illustrates his best type of flappers (Fig. 52) and a new gunpowder motor (Fig. 53) which works them in model form.	
45. <i>An Instrument for Testing Streamlining: 1850</i>	143
In the form of a whirling arm, this is the first instrument in history for testing aeronautical streamlining (Fig. 54).	
46. <i>The Whirling Arm for Large-scale Testing: 1850</i>	145
He describes and illustrates his last whirling arm, that for testing large aerofoils (Fig. 55).	
47. <i>Cayley's Improvement on Luntley's Airship Design: 1851</i>	147
He criticises Luntley's helically grooved airship, and suggests a flat helical fin (Fig. 56).	

	<i>Page</i>
48. <i>The Developed Man-Carrying Glider Design</i> ("governable parachute"): 1852	149
He describes and illustrates (Figs. 57, 58) a design which is, in essence, the modern aeroplane without its engine, with inherent longitudinal and lateral stability, and pilot-operated elevator and rudder; also an "umbrella" design (Fig. 59).	
49. <i>The Compound Designs and Part of the French Paper</i> : 1853 . . .	157
He describes and illustrates (Figs. 60-66) his designs for compound machines; also an improved tension wheel (Fig. 67).	
50. <i>The Improved Riding Rudder Glider Model</i> : 1853	172
In the French paper he also describes and illustrates (Figs. 68, 69) an improved model glider, evolved from his 1849 model.	
51. <i>The Improved Helicopter Model</i> : 1853	175
Also included in the French paper, he describes and illustrates (Fig. 70) an improvement on his 1792 helicopter model, with a single rotor of tin: noted here, too, is a brief mention of a possible rotor-parachute.	
52. <i>The First Successful Man-carrying Machine</i> (the "new flyer"): 1853	177
The accounts, and probable configuration (Figs. 71, 72 and Pl. IV) of the coachman-carrier and its flight.	
53. <i>The Tandem-Wing Model Designs; and a Stretched Rubber Motor</i> : c. 1853	184
He designs two tandem monoplane models, one a glider (Fig. 73) and the other powered (Fig. 74 and Pl. IV); also a stretched rubber motor, probably for the latter (Fig. 75).	
54. <i>The Complex Multiplane Designs</i> : c. 1853	188
The last new type of aircraft he concerns himself with is a multiplane comprising an upper main wing, with tandem biplane monoplane wings below, and amidships flappers (Figs. 76-81 and Pls. V, VI).	
55. <i>The Last Surviving Contribution to Aeronautics</i> : 1855	197
His last surviving contribution to aeronautics is a refinement on his improved helicopter model of 1853, in the form of annotated pen and wash drawings (Pl. VI).	
56. <i>Conclusions</i>	199
Appendix I. Cayley's triple paper "On Aerial Navigation" (1809-10)	211

	<i>Page</i>
Appendix II. A note on Cayley's aerodynamics. By J. L. Nayler	238
Appendix III. Cayley's swinging plate anemometer . . .	239
Appendix IV. An aircraft model attributed to Cayley . . .	241
Appendix V. A reminiscence of 1810 or 1811. . . .	242
Postscript	244
Glossary	245
Bibliography	251
Index	257

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