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MODERN ENGLISH IN AEROSPACE INDUSTRY

СОВРЕМЕННЫЙ АНГЛИЙСКИЙ В АЭРОКОСМИЧЕСКОЙ ОТРАСЛИ

Рекомендовано Учёным и Редакционным советами
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Данное учебное пособие предназначено для студентов магистратуры всех факультетов авиационных вузов. Представленные в издании тексты и упражнения посвящены наиболее значительным достижениям аэронавтики и космонавтики, а также обзору современных достижений в области аэрокосмической индустрии, связанных с разработкой, проектированием и эксплуатацией летательных аппаратов.

Цель пособия – развитие у магистрантов межкультурной коммуникативной профессионально-ориентированной компетенции. Пособие направлено на подготовку студентов магистратуры к самостоятельному чтению, пониманию и обсуждению научно-технической литературы авиационно-космической тематики на английском языке.

Учебное пособие составлено в рамках разработанного на кафедре УМК по дисциплине «Иностранный язык». Пособие соответствует программе по дисциплине для подготовки магистрантов в неязыковых вузах Российской Федерации.

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ПРЕДИСЛОВИЕ

В настоящее время английский язык превратился в язык общения в сфере профессиональной коммуникации. Подготовка по иностранным языкам в магистратуре ориентирована на область научных исследований обучающихся студентов и осуществляется в соответствии с их профессиональными потребностями и интересами.

Целью пособия является формирование у магистрантов комплекса необходимых для учёного речевых умений, таких как: чтение и перевод специальных текстов; обсуждение научно-технической литературы авиационной и ракетно-космической тематики; изложение результатов своих исследований на английском языке (в виде доклада, презентации).

Представленные в пособии тексты посвящены наиболее значительным достижениям аэронавтики и космонавтики, а также обзору современных технологий, связанных с разработкой и эксплуатацией летательных аппаратов. Задания и упражнения направлены на закрепление лексического материала.

Приложение включает в себя дополнительные тексты.

Учебное пособие написано в соответствии с положениями монографии «Общеевропейские компетенции владения иностранным языком»: Изучение, обучение, оценка» и с программой учебной дисциплины «Иностранный язык» для подготовки магистров.

Настоящее учебное пособие предназначено для студентов магистратуры обучающихся по направлениям 24.04.01 «Ракетные комплексы и космонавтика», 24.04.03 «Баллистика и гидроаэродинамика», 24.04.04 «Авиастроение», 24.04.05 «Двигатели летательных аппаратов». Пособие, также, может быть использовано на занятиях по английскому с магистрантами, обучающимися по другим направлениям авиационного и аэрокосмического профилей.

UNIT 1.
AIRCRAFT THAT CHANGED THE WORLD

World changers. It's almost easier to explain what we don't mean by that phrase than to define what we do. We have not compiled a list of trailblazers, like the de Havilland Comet, the world's first jetliner. Nor is this a list of airplanes that represent the greatest advances of aeronautics, such as the experimental aircraft that led to supersonic flight. Rather, we looked for craft that had an impact beyond the realm of things that fly, that reached into the larger culture and touched even those who aren't frequent fliers or connected to aviation. Some of our choices are individual airplanes that happened to play a critical role in a world-changing event; others are aircraft types that were so significant in commerce or in war that we could truly say of them: "These changed history."

Wright 1905

We wanted to start with a Wright airplane, but which most deserved the title of world changer? Wright biographer Tom Crouch, a National Air and Space Museum curator of early flight, nominated the brothers' third powered aircraft. "The 1905 was the world's first practical airplane," he observes.

"The best of the four flights made by the 1903 aircraft at Kitty Hawk, North Carolina, on December 17, 1903, was only 852 feet in 59 seconds," Crouch continues. With that success in hand, the Wrights decided to transfer flight operations to Huffman Prairie, eight miles east of their hometown, Dayton, Ohio. They built and tested two aircraft there, one during 1904 and another in 1905.Over the course of those two seasons, the Wrights fine-tuned their design, stretching the aircraft to improve stability and control, enlarging the control surfaces, and improving the propellers. The same engine, a virtual replica of the one that powered the 1903 aircraft, powered both the 1904 and 1905 models. On October 5, 1905, Wilbur Wright flew a distance of 24.5 miles in 59 minutes, 23.8 seconds. The brothers had finally achieved their original dream: developing a practical airplane capable of remaining aloft for a significant time and maneuvering under the full control of the pilot.

The brothers had not left the ground since the October 5, 1905 flight, however. In addition to brushing up on their flying skills, they had to make their first flights with a passenger and operate a new set of controls necessitated by upright seating.

They pulled the 1905 machine out of storage and modified it with two upright seats and the new control system. They shipped it back to the Kill Devil Hills of North Carolina because they wanted to undertake the test flights in an area with steady winds, soft sand, and isolation from prying eyes. On May 14, 1908, first Wilbur and then Orville took their mechanic, Charles Furnas, up for a ride. These were the first airplane passenger flights in history.

The Wrights had identified the final goal as a ‘machine of practical utility.’ They understood that the 1903 airplane, although embodying all the key technology, was not quite that. When they could stay aloft for an extended period, under the sure command of the pilot, and consistently land safely, they knew they had that ‘machine of practical utility.’ The 1905 machine was that airplane. When the Wrights were regularly flying over Huffman Prairie in the fall of 1905, that’s when the world truly changed.

Junkers F13

The F13 was essentially the first aircraft to anticipate the onset of ‘modern’ air transport: cantilever, no wing struts, all metal, low wing, monoplane, streamlined by the standards of the day. The metal construction made it sturdier and less vulnerable to damage than the wood-and-fabric biplanes of its competitors. The metal was especially critical in resisting heat and humidity in tropical countries.

The F13 first flew in 1919 (as the J13), and by the end of the year was in commercial service in Germany. It established Junkers in a position of global air transport dominance that his firm would not relinquish until the mid-1930s. The F13 was used in the first airline service in the Americas.

Unlike postwar transport airplanes that were modified from military types, the F13 was designed to carry passengers in an enclosed cabin. The four cushioned seats had seat belts, and the cabin was lighted and had picture windows.

After World War I, Germany was prohibited from operating the aircraft, but it sold them or licensed manufacture to 30 countries, including Hungary, Iceland, the Soviet Union, and Japan. In those years, the F13 established air routes in both Europe and the Americas. The last retired in 1948.

Boeing 314

In the hands of Pan American Airways, Boeing’s majestic flying boat, the 314, established mail and passenger routes across the north Atlantic, south Atlantic, and Pacific. The B 314 flying boat put up all kinds of records, but none could compare with the establishment of the North Atlantic service in 1939 in the epoch-making series of inaugural flights which were, perhaps, Pan American’s greatest contribution to air transport in all its distinguished history.

On the 314’s Pacific route service was opulent – even the flight deck was described as luxurious – with a lounge, dining area, sleeping berths, and dressing rooms, as well as chefs and china from four-star hotels. The 314s were the stars of Pan Am’s fleet for only three years; World War II shut down commercial operations. Still, it was not until the 1960s, with the debut of wide-body airliners such as the Boeing 747, that the B-314s were dethroned as the world’s largest scheduled-use commercial aircraft.

Mikoyan-Gurevich MiG-15

Still a hot-looking airplane 59 years after it entered service, the Mikoyan-Gurevich MiG-15 made its mark during the Korean War as the Soviet Union’s first jet-powered day interceptor with a pressurized cabin and an ejection seat.

The MiG-15`s mission was to pick off U.S. bombers, which led to storied dogfights between the MiGs and the fighter escorts, North American F-86s. Though an improved version of the MiG-15 could climb higher and faster than the F-86, U.S. Air Force pilots generally made up the difference with better aerial combat training. Still, the 670-mph MiG-15 put the world on notice that the U.S.S.R. could build cutting-edge aeronautical technology. The MiG-15 also possessed a certain aesthetic quality: sleek, fast – the very embodiment of what a jet fighter should be.

Its performance must have reinforced that impression. More MiG-15s – 12,000 – have been made than any other jet aircraft in history, counting licensed versions made in other countries, the number reaches 18,000. The type has been sold to 43 countries – from Sri Lanka to Cuba to Uganda.

Sikorsky S-55

While the helicopter – with its enviable ability to hover, dart in all directions, and land virtually anywhere – had achieved a measure of success in the 1930s and 1940s, it wasn't until the Sikorsky S-55 made its debut with the U.S. Navy in Korea in 1950 that rotary-wing history was utterly transformed.

The dazzling success of the S-55–both nationally and internationally – was based on the aircraft's ability to fill multiple roles: troop and cargo transport, air assault, and casualty evacuation. That versatility resulted in unprecedented demand – 1,700- were built, more than any previous helicopter type.

The design was brilliant: Sikorsky Aircraft completely reconfigured its earlier layouts to create the first helicopter with a cabin capable of carrying 10 passengers or seven stretchers, and moved the engine to the nose, enabling easier maintenance and solving the center-of-gravity problems previous single-rotor models had experienced. By the end of the Korean War, Sikorsky's machine had rescued downed pilots, saved the lives of 10,000 wounded soldiers, and delivered escaped prisoners.

In addition, the S-55 served as the core of counter-insurgency efforts by the British in Malaya and the French in Indochina, pushing both nations to establish their own helicopter programs. In American and foreign civil service, the S-55 pioneered helicopter airline transport.

Boeing 747

So great a technological achievement was the Boeing 747 airliner that some historians have called it the 20th century's cathedral. Nearly 40 years after its first flight, it remains, along with the photograph of Buzz Aldrin standing on the moon, the most recognizable symbol of U.S. engineering. When it was introduced, airports the world over reinforced runways and made other infrastructure changes to receive it.

Still, it is not grandeur or technology or even impact on infrastructure that qualifies it for a place on this list. It was, after all, an evolutionary design. Its creators believed it was merely an interim answer to the demand that airlines would eventually meet with a revolutionary supersonic transport. They predicted, it would relegate the 747 to hauling cargo.

And what qualifies the Boeing 747 as a world changer is that since it entered service in 1970, 96 carriers around the world have used the wide-bodies to fly 3.5 billion people to their destinations. ***[50 Aircraft That Changed the World, 2010].***

Exercises

1. Find out the English equivalents for the following expressions in the text: достижения аэронавтики; перевозить на самолете к месту назначения; транспортировка грузов; катапультируемое сиденье; укреплять взлетно-посадочную полосу; перевозки вертолетными авиакомпаниями; истребитель-перехватчик; герметичная кабина космического корабля; на реактивной тяге; центр тяжести; перевозка пассажиров и грузов; воздушный бой; винтокрылый летательный аппарат; аэронавигационная техника; развивать воздушные перевозки; обтекаемый корпус самолета; полеты с пассажирами на борту; крыло распорки; управлять самолетом; мало уязвимый к разрушению; самолет разбивается; сделать вынужденную посадку.

2. Complete the text with the words from the box:

GPS-guided	operational ceiling	unmanned aircraft (2)	aerial vehicle	synthetic aperture radar
fly missions	sensor operator	flying robot (2)	anti-armor missile	surveillance missions

In November 2002 a vehicle traveling in Yemen and believed to be carrying terrorists was destroyed by a missile. It was executed by a … . The first … has changed the rules of warfare. Built by General Atomics Aeronauitical Systems, the… has been operational. Since 1995 and now is … … in Afghanistan and Iraq. The Air Force deployed the latest version to Afghanistan last October.

The vehicle, which has an … … of 50000 feet, is flown remotely by a “pilot” and two … … housed in a trailer on the ground. The aircraft has a nose camera, variable-aperture TV and infrared cameras, and a … … to see through smoke, clouds, or haze. The RQ (R for “reconnaissance”, Q for “unmanned”) model flies long-endurance, medium-altitude … …, two laser-guided bombs, and a 500-pound, … precision bomb.

Today, some countries are increasing their use of … … for civilian missions, such as law enforcement, border control, and ocean surveillance. Even Holywood has discovered their potential, putting them to work as movie camera platforms. Here`s an … … that has changed not just the real world but the world of fantasy as well.

3. Match the words from the text (1-6) with their definitions (A-F). Translate the words:

1	Aircraft	A	the science involved with the study, design, and manufacturing of air flight capable machines, and the techniques of operating aircraft and rockets within the atmosphere
2	Control system	B	A fixed-wing aircraft with one main set of wing surfaces in contrast to a biplane or other multiplane
3	Monoplane	C	a type of transportation service for transporting passengers and air cargo
4	Aeronautics	D	a type of fighter aircraft designed specifically to intercept and destroy enemy aircraft
5	Interceptor	E	a machine that is able to fly by gaining support from the air or the thrust from jet engines
6	Airliner	F	a device or set of devices, that manages, commands, directs or regulates the behavior of other devices or systems

4. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

aeronautical	destinations
jet	airline transport
rotary-wing	evacuation
to establish	the center-of-gravity problems
to fly to	cargo
to stand	downed pilots
hauling	on the moon
to pioneer	fighter
to solve	helicopter
casualty	technology
to rescue	helicopter programs

5. Which words on the left have a similar meaning to those on the right?

1	airliner	A	escape crew capsule
2	cargo	B	to satisfy the requirements
3	engineering	C	rotorcraft
4	to meet the demands	D	self-propelled munition system
5	ejection seat	E	goods being conveyed
6	dogfight	F	aircraft
7	missile	G	aerial battle
8	helicopter	H	technology

6. Complete each sentence (1-6) with one of the endings (A-F):

1	The Wrights had been granted a patent and had signed contracts	A	enlarging the control surfaces and improving the propellers.
2	Germany was banned from operating aircrafts after World War 1,	B	still the MiG-15 put the word on notice that the U.S.S.R. could build cutting-edge aeronautical technology
3	The MiG`s mission was to bring down bombers,	C	capable of carrying passengers, and moved the engine to the nose, enabling easier maintenance and solving the center-of-gravity problems.
4	The brothers fine-tuned the design, stretching the aircraft to improve stability,	D	but it sold many of them or licensed manufacture to 30 countries, including Hungary, Iceland, Japan and the U.S.S.R.
5	An improved version of the MiG-15 could climb higher and faster than the U.S. fighter escorts,	E	which led to dogfights between the MiG`s and the fighter escorts.
6	The aircraft reconfigured its earlier layouts to create the first helicopter with a cabin	F	to sell airplanes to both to the U.S. Army and a French syndicate.

7. Grammar.

Английские глаголы имеют 4 формы: инфинитив, прошедшее время, причастие II, причастие I.
to transfer (перевозить), transferred (перевозил),transferred (перевезенный), transferring (перевозящий)
sell (продавать), sold (продал), sold (проданный), selling (продающий).

Find out similar forms in the text and translate them into Russian. Translate the next sentences into Russian:

1. NASA is delighted at the continued progress made possible by some investments in commercial space.
2. We look forward to next missions of other commercial partners, including commercial crew launches in the near future.
3. The pressurized cargo module has been extended, allowing more cargo to be delivered with each mission.
4. The first microsatellite will be deployed from the space station and experiments will study the behavior of gases, including experiments in physical science and Earth science.
5. The Space Automated Lab is a new space life science facility that is designed to support a wide variety of fundamental research.
6. The propulsion-capable satellite was deployed from the Nanodeployer known as Kaber.
7. The satellites, sponsored by NASA and developed by the Research Center, consist of two sats weighing 4,5 pounds each

UNIT 2.
BOEING COMMERCIAL AIRPLANES

Now the world's largest aerospace company, Boeing was founded in 1916 by William E. Boeing in Seattle, Washington. The company is composed of multiple business units: Boeing Commercial Airplanes (BCA); Boeing Defense, Space & Security (BDS); Engineering, Operations & Technology; Boeing Capital; and Boeing Shared Services Group. As top U.S. exporter, the company supports airlines and U.S. and allied government customers in 150 countries. Boeing's products and tailored services include commercial and military aircraft, satellites, weapons, electronic and defense systems, launch systems, advanced information and communication systems, and performance-based logistics and training.

Boeing Commercial Airplanes Boeing has been the premier manufacturer of commercial jetliners for over 40 years. Today, their main commercial products are the 737, 747, 767,777 and 787 families of airplanes and the Boeing Business Jet. The company has nearly 12,000 commercial jetliners in service worldwide, which is roughly 75 percent of the world fleet. Through Boeing Commercial Aviation Services, the company provides round-the-clock technical support to help operators maintain airplanes in peak operating condition. Commercial Aviation Services offers a full range of world-class engineering, modification, logistics and information services to its global customer base, which includes the world's passenger and cargo airlines, as well as maintenance, repair and overhaul facilities.

Capital Investment Decisions

Capital investment decisions at Boeing are unique and—to some degree—risky. For example, in the mid-1950s, despite failing to profit on civilian planes in two decades, Boeing spent $185 million to develop the first American all-jet transport, the 707, despite not having made money in a non-military plane in twenty years, Boeing spent $185 million to develop the 707, the first American all-jet transport. To put this in context, this capital investment was $36 million or 25% more than Boeing's total net worth of $149 million in 1956!

Boeing's attitude toward risk can be better understood if we look at the company's earnings during that time. From 1946-49, Boeing's average annual net income was less than $1.4 million. From 1950-53, average net income increased to $12 million as the company benefited from its military aircraft business, led by its signature B-52 jet bomber. Since the cost of building a prototype commercial jet aircraft was estimated to be $15 million (versus the eventual/ actual cost of $16 million), Boeing determined it was too great a risk as a stand-alone project. The numbers implied such a project would put the entire company at grave financial risk. At that time airlines were reluctant themselves to commit their financial stake entirely on reliance or use of jet aircraft alone.

However, Boeing determined the risk of launching a commercial jet aircraft was worth undertaking given the following additional considerations. As it turned out, Boeing's B-52 jet bomber fleet deployment worldwide necessitated demand for a tanker jet-aircraft for refueling purposes. Existing prop aircraft flew too slow and too low for efficient refueling. Given the aforementioned sharp increase in average net income, Boeing determined that the $15 million+ cost to develop a prototype 707 would be less risky because it would be designed to serve two (instead of one) potentially very large global markets, thereby lowering risk and increasing expected returns.

In 1955, Boeing secured an order for production of 400 military units from the US Air Force for its 707 model, equal to the projected (and eventual) installed base of B-52s for US Strategic Air Command.

With this strong endorsement of the 707 aircraft and burgeoning world travel, commercial airlines started to express interest. Boeing was able to differentiate itself from both foreign and domestic competitors by maintaining flexibility with its own customers. Specifically, Boeing was able to widen its cabin space by four inches with minor engineering and tooling costs plus retain the core features incorporated into its military prototype. This enabled Boeing to have faster time-to-market deliveries and higher absorption rate of fixed overhead for both military-and-commercial aircraft assembly operations. Total 707 commercial deliveries were 1011 (from 1958-94).

During the 1954-58 cycle in which Boeing invested heavily in the 707, corporate Net Income was stable-to-lower while Total Liabilities increased 2.3 times. In 1954, Net Income and Total Liabilities, respectively, were $32.4 million and $171.9 million.
By 1958, Net Income was $29.4 million and Total Liabilities were $403.7 million, or Total Liabilities exceed annual Net Income by a factor of 13.7. By comparison, during1950-53, average Total Liabilities exceeded average annual Net Income by a factor of 12.

Stock Price. Investors initially responded positively to the new project. The Company's stock price reached a high of $79.63 in 1955 and then fluctuated for the next three years going down to $36.62 in 1957 and then up to $45.62 the following year.

In sum, Boeing did "risk the company," as measured by the cost to develop the program ($185 million) versus its net worth ($149 million) with the prototype exceeding its average annual Net Income ($16 million versus $12 million) over the same period. But this risk was tempered by leveraging the cost over two end-user markets rather than one. Additionally, Boeing established a sales-and-earnings platform on an already strong, well-established business (defense/military) that could be adapted for creating a civilian commercial segment. Earning power as measured by Net Income increased at about the same rate (2.5x) as the increase in Total Liabilities (2.3x) when measuring the 1954-58 period with the pre-707 era of 1950-53.

Significant financial payback took longer to occur. While Boeing achieved breakeven with the 707 in late 1956, the long-term nature and large capital investment for the aircraft business meant that it took 10 years for the 707 to reach peak-production while simultaneously helping the company achieve peak-earnings in 1967-68. Unit deliveries for the 707 in 1967-68 were 118 and 111, respectively, as company Net Income exceeded $83 million both years.

After the 707: SST, Wide Body Jet Aircraft, Bigger Bets and Bigger Risk. By the mid-1960s, Boeing had firmly established itself as a leader in commercial jet aircraft with the 707 as its flagship product worldwide. In anticipation of demand for supersonic jet travel, and with airlines extrapolating the shift of passengers from trains and transoceanic ships into a need for wide-body jet aircraft, Boeing made an even bigger bet by simultaneously pursuing both markets. Boeing did this without having the military aircraft market as a "hedge" or back-up like it did with the 707. Boeing appeared to be flying high with Net Income topping $83 million in 1967 and 1968, concurrent with triple-digit unit deliveries of the flagship 707 aircraft each of those years. However, Net Income dropped 88% to $10.2 million in 1969 as economic slowdown, declining air travel and financial retrenchment by the airline industry caused 707 unit shipments to fall by nearly 50%. In such a weak economy, Boeing only delivered four 747s in 1969, which implied low absorption of fixed overhead and profit margin pressure. Federal funding of the SST was cancelled in 1971, forcing Boeing to take a loss on this project.

During a peak in the late 1960s and a bottom in 1971, the stock fell 88% as the development of a supersonic transport to compete against the Concorde was called off. And in response to the sharp decline in demand for commercial jet aircraft, Boeing cut its commercial aircraft workforce from 83,700 in 1968 to 20,750 in 1971.

The only reason Boeing did not fail was due to the financial offset by its strong, stable military business in the form of its Minuteman and Cruise missile programs. Eventually, the long-expected increase in air passenger travel materialized and the accompanying need for wide-body jet aircraft gained momentum with Boeing's 747 as the prime beneficiary.

Boeing's financial resurgence, its diverse family of aircraft (narrow-and-wide body models) able to serve all worldwide markets and its strong, stable military business enabled it to outlast and outdistance its competitors. Lockheed exited commercial aircraft in 1981, with McDonnell Douglas and European Air Bus remaining as prime competitors, but with far fewer product offerings versus Boeing. By 1997, McDonnell Douglas was acquired by Boeing, thereby eliminating it as a competitor.

The commitment of capital and time associated with being a leader in commercial aircraft would appear to support a "bet the company approach" with each successive generation of new jet aircraft. However, Boeing has utilized different tactics to achieve financial success and maintain its market leadership. The 767 was the company's first twin-jet wide-body model; the 777 was the first "fly by wire" airliner and the first computer-designed commercial jet aircraft; the 787 is comprised of over 80% composite materials enabling it to be more fuel efficient due to significantly less weight. Boeing has diversified (and thereby lowered) its risk by outsourcing manufacture of key components and sections of its aircraft models while retaining the design, development and final assembly functions.

This lower degree of vertical and horizontal integration versus the approaches taken in its 707 and 747 models has enabled the company to more efficiently utilize all its resources while still taking the necessary risks to maintain its leadership. As noted earlier, the success of Boeing's 707 and 747 programs can be partly attributed to the company's core competency in military and defense sectors. The 707 was launched on the basis of potentially, and ultimately serving two very large markets, commercial and military. Thus, the company's missile business was able to sustain Boeing's overall financial viability while the company weathered the industry downturn in the early 1970s. As the company launched its later generations of jet aircraft, military/defense business remained a key contributor to overall corporate success for the same reasons noted for the 707 and 747. The company`s strategic posture was further strengthened when Boeing acquired Mc Donnell Douglas, which was the largest military aircraft player. ***[World Air Cargo Forecast, 2015].***

Exercises

1. Complete the text with the words from the box. Mind the use of Gerund and Participle:

acquiring	driving out	sharing	providing	jet aircraft
increasing	successively	earnings	buying out	strategy
launching	jet aircraft	accommodating	defense-related	raising

Boeing's the company (1) appears to have (2) increased earnings power (measured by Net Income) with each generation of new commercial (3). Each new revolutionary jet aircraft program eventually is the primary driver in (4) total Net Income by several-fold (versus the cycle immediately prior to it). The 707 led to a 2.5x increase in Net Income (late 1950s/early 1960s versus mid-1950s) and by 1967-68, Net Income was 2x higher than its 1961 level. The 747 helped Boeing surpass the 1967-68 peak by a factor of 7-times by 1980, with the

767 and 777 programs leading to an eventual 7-fold improvement in Net Income by 2011 versus 1980.

Boeing's success in commercial jet aircraft stemmed from its military aircraft business in terms of risk (5) (e.g., 707 and its military KC-135 version) and diversification. The strong position in (6) projects (e.g., Minuteman and Cruise missiles) provided stable, steady cash flow for the entire corporation thereby (7) an additional financial cushion to undertake development of new generations of jet aircraft. The acquisition of the largest US military contractor, McDonnell Douglas, further strengthened Boeing's corporate business portfolio in terms of (8), cash flow and diversification.

Cyclical, financial and execution risks remain perennially relevant for the commercial jet aircraft business. However, Boeing has a proven performance record of being able to maintain its market leadership and (8) its earning power with each generation of new aircraft. This includes, but is not limited to, (9) unique customer demand requirements on a global scale, rationalization in down cycles, improvement of assembly and (10) processes and either (11) for example (12) McDonnell Douglas or (13) (e.g., Lockheed) its major US commercial jet aircraft competitors.

While Boeing's stock price has been cyclical, investors have learned to be patient every time the company undertakes a bigger bet when (14) a new generation of aircraft.

2. Give Russian equivalents for the following expressions:

(1) multiple business units, (2) allied government customers, (3) tailored services,(4) defense systems,(5) launch systems, (6) advanced information and communication systems, (7) performance-based logistics,(8) commercial jetliners, (9) round-the-clock technical support,(10) maintain airplanes, (11) peak operating condition,(12) passenger and cargo airlines, (13) maintenance, repair and overhaul facilities,(14) all-jet transport,(15) fleet deployment, (16)prop aircraft,(17) the US Air Force, (18) US Strategic Air Command, (19) aircraft assembly operations, (20) Total Liabilities,(21) annual Net Income, net worth, (22)flagship aircraft,(23) supersonic transport,(24) Cruise missile,(25) air passenger travel,(26) narrow-and-wide-body jet aircrafts, (27) "fly by wire" airliner, (28) computer-designed jet aircraft, (29) assembly and manufacturing processes.

3. Rearrange the words to make sentences:

1. /New/ have/ investors /to/ patient/ be /learned/ when/ aircraft/ launching/ a/ generation/ of.
2. In terms of/ success/ stemmed/ risk/ aircraft/ commercial/ sharing/ military/ business/ its/ from/ in/ jet aircraft/ Boeng`s.

3. Launched/ basis/ the/of/ military/ two/ large/ was/ 707/ on/ the/ serving/ very/ commercial/ markets/ and.
4.Leadership/ Boeing/ tactics/ utilized/ achieve/ maintain/ success/ market/ has/ to/ financial/ and/ market/its/different.
5. Funding/ cancelled/ this/ forcing/ a/ take/ Boeing/ project/ to/ loss/ federal/ was/ on.
6. A/ Determined/ launching/ commercial/ worth/ risk/ Boeing/ the/ of/ undertaking/ was/ jet aircraft/
7. At/ capital/ decisions/ unique/ to/ risky/ some/ are/ investment/ Boeing/ and/ degree/.
8. Round-the-clock/ operating/ in/ airplanes/ technical/ to/ operators/ airplanes/ peak/ company/ support/
9. The/ of/ 40/ been/ years/ commercial/ premier/ has/ Boeing/ the/ over/ manufacturer/ jetliners/ for.

4. Match the sentence halves:

1	The company has nearly 12000 commercial jetliners in service worldwide,	A	to help operators maintain airplanes in peak operating condition.
2	Through Boeing Commercial Aviation Services, The company provides technical support	B	which is roughly 75 percent of the world fleet.
3	Services offers a full range of engineering, modification, logistics and information services to its customer base,	C	Boeing determined that the cost to develop a prototype 707 would be less risky.
4	Given the sharp increase in average net income,	D	as its flagship product worldwide.
5	Boeing had firmly established itself as a leader in commercial jet aircraft with the 707,	E	which includes the world`s passenger and cargo airlines.
6	While Boeing achieved break even with the 707 in late 1956,	F	providing an additional financial cushion to undertake development of new generations of jet aircraft.
7	During a peak in the late 1960s and a bottom in 1971,	G	enabling it to be more fuel efficient due to significantly less weight.
8	The 787 is comprised of over 80% composite materials	H	the stock fell 88% as the development of a supersonic transport to compete against the Concorde was called off.
9	The strong position in defense-related projects provided stable, steady cash flow for the entire corporation	I	the long-term nature and large capital investment for the aircraft business meant that it took 10 years to reach peak-production

5. Complete the text with the words from the box:

revenue	the shipping	downloading	award-winning	utilizing
comprising	including	life-saving	online booking	boarding passes
offered	the passenger fleet			

American Airlines

American Airlines Cargo, a division of American Airlines Group, provides more than 100 million pounds of weekly cargo capacity to major cities in the United States, Europe, Canada, Mexico, the Caribbean, Latin America and Asia. Cargo provides one of the largest cargo networks In the world, with cargo terminals and interline connections available across the globe. (1) the cargo capacity of (2) American Airlines Cargo facilitates (3) of many product types (4) fresh flowers, fruit, vegetables, seafood and (5) pharmaceuticals. The cargo business has an international focus, (12) (6) approximately 12 percent of international (7) and 4 percent of total American (8).

American`s (9) website, aa.com, allows customers to conveniently search for and book air fares and award travel; select seats; make hotel; rental car and cruise reservations; get flight arrival and departure information; sign up for flight status notifications, and even check-in and print (9) passes. Customers can also manage their advantage accounts on aa.com, as well as sign up to receive email offers. Customers who purchase tickets on aa.com never pay an (10) fee and get a lowest price guarantee on fares and all products (11) on the site. American customers can also stay connected by (12) American`s mobile app or follow it on Twitter or Facebook.

UNIT 3.
EXPERIMENTAL INVESTIGATION INTO THE CONTROL AND LOAD ALLEVIATION CAPABILITIES OF ARTICULATED WINGLETS

For the majority of the last century, the primary means for aircraft control though the use of elevators for pitch control, ailerons for roll control, and a rudder for yaw control has remained largely unchallenged. For aircraft designers around the world this control methodology represents the most reliable, robust, generally applicable, and effective means of aircraft attitude control that currently exists. While it is certainly true that this method of aircraft control has become much more complex as the rapid advance in aerospace technologies continues to accelerate, a wide-ranging successor to this traditional method that can significantly improve upon this baseline method, giving substantial improvements in efficiency and performance continues to remain operationally complex and/or difficult to justify.

While this required and necessary search remains ongoing, in large part to meet the ever-increasing demands on future aircraft operational effectiveness and environmental impact, the use of this traditional method of aircraft control does rely on the deflection of hinged, discrete control surfaces, which can, even undermoderate levels of deflection, set up localised areas of severe adverse pressure gradient (typically along the hinge line) that both promote and produce regions of flow separation. Under these conditions, both control surface and overall wing efficiency is reduced leading to suboptimal aircraft performance. This drawback of the current system is one of the main reasons the search for “morphing” aircraft systems and technologies continues. If successful, and through using control configurations that allow more general and subtle changes in streamwise curvature, morphing for control may lead to increases in aerodynamic efficiency while maintaining comparable performance.

Unfortunately, however, the widespread use of modern morphing aircraft control systems remains largely unrealised since a rigorous cost/benefit analysis has not demonstrated a significant improvement upon current aircraft axis control methodologies. Together with using traditional control surfaces for direct aircraft axis control, more and more studies of late have considered using smaller, more microscopic deflections of these control surfaces in flight to increase the performance and efficiency of aircraft over more of the mission profile. Recent work has detailed investigations into the use of simultaneous deflection of flaps, spoilers, and/or ailerons to adjust streamwise curvature to aid performance enhancement, with the general consensus being that benefits are probable. Of the benefits possible, manoeuvre load alleviation, spanwise and chord wise lift distribution optimization (for minimum drag) as aircraft weight varies during flight as well as the placation of in-flight turbulence appear to be the most promising.

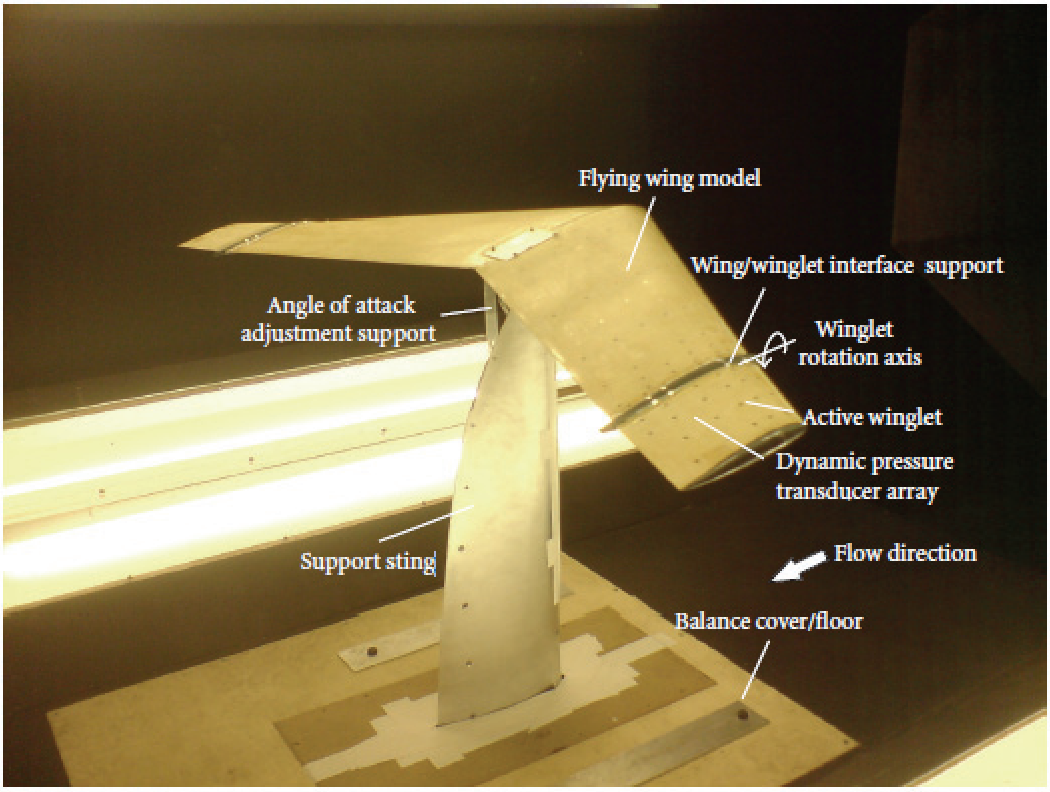

Figure 3: Experimental setup for active wing-tip flying wing.

Together with investigating in more depth the dynamics of this control methodology as a substitute for tradition aileron control systems, the ability of the system to be used as a means of real-time wing load alleviation during flight is also considered. The experimental model tested, analysed, and evaluated used two actively controlled wingtips (one mounted at each wingtip) that were free to rotate about the wing-tip chord axis line. The model was also purpose built to allow for multiple dynamic surface pressure measurement on one upper wing surface as well as mounted on a six-component force and moment balance to measure, under test conditions, the real-time aerodynamic and control loads during winglet actuation.

A schematic of the swept wing model designed and built for the test programme is shown in Figure 1.

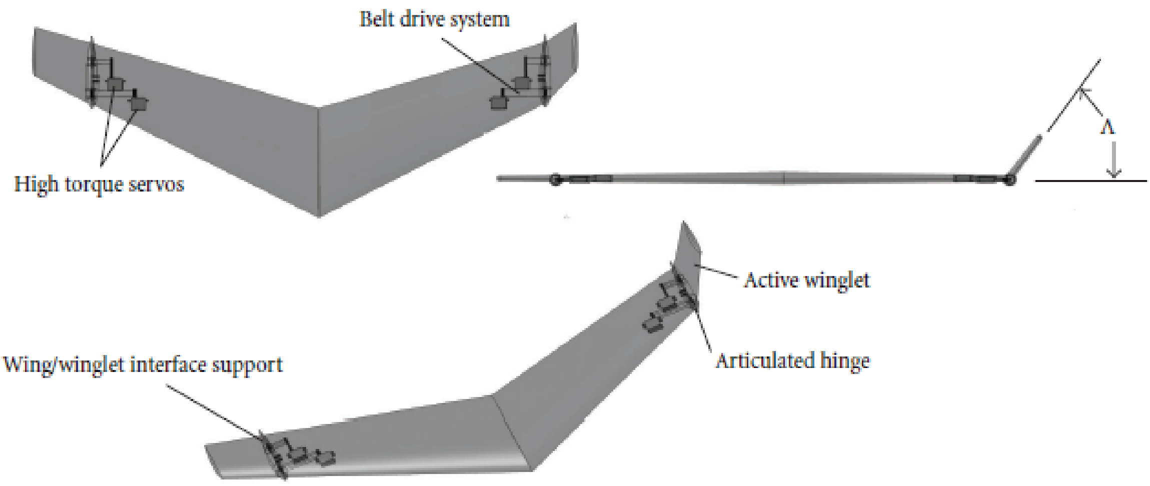

FIGURE 1: General schematic of the baseline flying wing with active winglets.

The baseline configuration (without winglets) used a Zagi 12 wing section, 30 deg leading edge sweep, a wingspan of 1.2m (1.54m with winglets planar), zero washout, and root and tip chords of 0.326m and 0.185 m, respectively. All sections of the complete wing (comprising the main baseline wing sections and the winglets) were made of a blue foam core that was reinforced and strengthened with a bonded carbon and lacquered skin to further resist aerodynamic loading and produce an aerodynamically robust surface finish. To build the flying wing configuration, the two mirrored baseline semispan wing sections were mated and glued together at the root using additional carbon stiffening rods for extra strength.

Prior to assembly, and to allow for the integration of the active wing-tip actuator assembly and the array of dynamic pressure transducers, sections of the under-surface of each baseline wing semi span section at the wing tip were removed. Internal portions of the blue foam core within the starboard (looking from behind the model) baseline semi span wing and winglet were also removed to accommodate integration of dynamic surface pressure transducer array.

The use of articulated winglets on a baseline swept wing configuration to both produce first-order control forces and moments as well as provide load alleviation capabilities to the combination has been experimentally investigated. From force and moment results taken from the model together with dynamic surface pressure data taken from the upper wing and winglet surfaces, the concept gives good evidence that the methodology can provide adequate roll control authority as well as a significant ability to adjust and tailor the lift distribution for application to second-order performance and efficiency enhancements.

[Gatto A., Bourdin P., Friswell M.I. Experimental Investigation into the Control and Load Alleviation Capabilities of Articulated Winglets. August 2012]

Exercises

1. **Look through the text and find the English equivalents for the following expressions:** руль высоты; регулирование шага; приведение в действие; схема полёта; не достаток; распределение подъёмной силы; матрица первичных преобразователей; широкомасштабный**;** верхнее крыло; законцовка крыла; искривление по потоку; ось самолёта; ось шарнира; управление креном; турбулентность в полёте; уменьшение нагрузок; управление по курсу; верхнее крыло; отклонение; улучшение показателей; в направлении потока.

2. **Complete the text with the words from the box:**

aircraft axis	drawback	stream wise curvature	hinge line	spoilers
ailerons	deflection	mission profile	morphing	lift distribution

While this required and necessary search remains ongoing, in large part to meet the ever-increasing demands on future aircraft operational effectiveness and environmental impact, the use of this traditional method of aircraft control does rely on the … of hinged, discrete control surfaces, which can, even undermoderate levels of … , set up localised areas of severe adverse pressure gradient (typically along the …) that both promote and produce regions of flow separation. Under these conditions, both control surface and overall wing efficiency is reduced leading to suboptimal aircraft performance. This drawback of the current system is one of the main reasons the search for "…" aircraft systems and technologies continues. If successful, and through using control configurations that allow more general and subtle changes in … , morphing for control may lead to increases in aerodynamic efficiency while maintaining comparable performance.

Unfortunately, however, the widespread use of modern morphing aircraft control systems remains largely unrealised since a rigorous cost/benefit analysis has not demonstrated a significant improvement upon current … control methodologies. Together with using traditional control surfaces for direct aircraft axis control, more and more studies of late have considered using smaller, more microscopic … of these control surfaces in flight to increase the performance and efficiency of aircraft over more of the … . Recent work has detailed investigations into the use of simultaneous deflection of flaps, spoilers, and/or … to adjust stream wise curvature to aid performance enhancement, with the general consensus being that benefits are probable. Of the benefits possible, manoeuvre load alleviation, span wise and chord wise …optimization (for minimum drag) as aircraft weight varies during flight as well as the placation of in-flight turbulence appear to be the most promising.

3. **Match the words from the text (1-6) with their definitions (A-F). Translate the words:**

1	pitch control	A	occurring or provided during an aircraft flight
2	rudder	B	a vertical projection on the tip of an aircraft wing for reducing drag
3	aileron	C	making something change direction
4	in-flight	D	a vertical piece of metal at the back which is used to make the plane turn to the right or to the left.
5	winglet	E	control of the pitching motion of an aircraft
6	deflection	F	a section on the back edge of the wing of an aircraft that can be raised or lowered in order to control the aircraft's movement

4. **Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.**

environmental	alleviation
baseline	enhancement(s)
load	impact
efficiency	operational effectiveness
aircraft	method
performance	distribution
in-flight	the ever-increasing demands
lift	comparable performance
to meet	turbulence
lead	axis
maintain	to increases in aerodynamic efficiency

5. **Which words on the left have a similar meaning to those on the right?**

1	drawback	A	widespread
2	impact	B	to satisfy the requirements
3	wide-ranging	C	disadvantage
4	to meet the demands	D	influence
5	placation	E	sustain
6	rely on	F	improvement
7	enhancement	G	cessation
8	maintain	H	depend on

6. **Complete each sentence (1-6) with one of the endings (A-F):**

1 If successful, and through using control configurations that allow more general and subtle changes in stream wise curvature	**A** to aid performance enhancement, with the general consensus being that benefits are probable
2 Recent work has detailed investigations into the use of simultaneous deflection of flaps, spoilers, and/or ailerons to adjust streamwise curvature	**B** the two mirrored baseline semispan wing sections were mated and glued together at the root using additional carbon stiffening rods for extra strength

3 To build the flying wing configuration	**C** a wide-ranging successor to this traditional method that can significantly improve upon this baseline method continues to remain operationally complex and/or difficult to justify
4 While it is certainly true that this method of aircraft control has become much more complex as the rapid advance in aerospace technologies continues to accelerate	**D** morphing for control may lead to increases in aerodynamic efficiency while maintaining comparable performance
5 Of the benefits possible, manoeuvre load alleviation, spanwise and chordwise lift distribution optimization (for minimum drag) as aircraft weight varies during flight	**E** sections of the under-surface of each baseline wing semi span section at the wing tip were removed.
6 Prior to assembly, and to allow for the integration of the active wing-tip actuator assembly and the array of dynamic pressure transducers,	**F** as well as the placation of in-flight turbulence appear to be the most promising

7. **Grammar. Complete the text with one word from the list in each space. Mind the use of Infinitives in the text. Translate the next sentences into Russian:**

to adjust to increase to aid to assembly to accommodate *to allow to build appear to be*

1. More and more studies of late have considered using smaller, more microscopic deflections of these control surfaces in flight … the performance and efficiency of aircraft over more of the mission profile.
2. Recent work has detailed investigations into the use of simultaneous deflection of flaps, spoilers, and/or ailerons … streamwise curvature … performance enhancement.
3. Of the benefits possible, manoeuvre load alleviation, spanwise and chord wise lift distribution optimization (for minimum drag) as aircraft weight varies during flight as well as the placation of in-flight turbulence … the most promising.
4. ... the flying wing configuration, the two mirrored baseline semispan wing sections were mated and glued together at the root using additional carbon stiffening rods for extra strength.
5. Prior …, and … for the integration of the active wing-tip actuator assembly and the array of dynamic pressure transducers, sections of the under-surface of each baseline wing semi span section at the wing tip were removed.
6. Internal portions of the blue foam core within the starboard (looking from behind the model) baseline semispan wing and winglet were also removed … integration of dynamic surface pressure transducer array.

UNIT 4.
MICRO- AND NANO-AIR VEHICLES: STATE OF THE ART

Micro- and nano air vehicles are defined as “extremely small and ultra-lightweight air vehicle systems” with a maximum wingspan length of 15 cm and a weight less than 20 grams. MAVs are defined as small flying systems which are designed for performing useful operations. In 1997, DARPA started a program called “MAV-project” where they presented some minimal requirements. In particular, they set the maximum dimension to be around 15 cm long, and the weight, including payload, to be less than 100 g. Furthermore, flight duration should be 20 to 60 minutes. In addition to the MAV-project, DARPA started another program called nano air vehicles, which focus on the aim “to develop and demonstrate an extremely small (less than 15 cm), ultra lightweight (less than 20 g) air vehicle system with the potential to perform indoor and outdoor military missions.”

NAVs are defined as small air vehicles with an operating range less than 1 km, a maximum flight altitude around 100 m, endurance less than one hour, and maximum takeoff weight (MTOW) of 25 g while MAVs are defined as 5 kg MTOW with endurance around 1 hour and an operative range around 10 km. When referring to both classes of systems, the term AVS (air vehicle systems) will be used.

Many research institutions are actively studying and developing new air vehicles, reducing size and weight while improving performance, and adding more functionality. Several companies and agencies also play an important role in the manufacturing and development of AVS. Examples here are DARPA from USA, Prox Dynamics from Norway, and Syma from USA.

AVS applications span a wide range, and the majority of them are military. AVS are capable to perform both indoor missions and outdoor missions in very challenging environments. The main applications are intelligence, surveillance, and reconnaissance (ISR) missions. These systems can provide a rapid overview in the area around the personnel, without exposing them to danger. Infrared (IR) cameras can give detailed images even in the darkness. Furthermore, NAVs, thanks to their reduced dimensions, are perfect for reconnaissance inside buildings, providing a very useful tactical advantage. Such small vehicles are currently the only way to remotely “look” inside buildings in the battlefield.

They can carry specific sensors such as gas, radiation or other sensors used to locate biological, nuclear, chemical, or other threats. They can, for instance, fly inside toxic clouds and transmit data or bring samples back to the base station, and, thus, provide vital information on the composition and extent of gaseous clouds and improve the assessment of danger. Some of the applications described above can be extended to the civilian field. For example, the police and the fire brigade could use the capability of indoor flights for inspecting unsafe or collapsed buildings in order to search for survivors or simply do a safety check of the building structure.

Since AVS would decrease the time necessary to explore a given area, they could be used in disaster cases, such as earthquakes, after hurricanes, or in collapsed mines. In these cases, locating survivors faster increase the probability of saving lives. However, AVS are not only related to high-risk applications, they can also be used as a support in regular police operations such as traffic control, crowd management or ordinary city surveillances.

Mass production of AVS will reduce the cost and, thus, enhance distribution among soldiers and policemen. This could render NAVs to be a natural part of the standard soldiers' equipment. In this case, one of the main features that NAVs must have is that they have to be ready for flight in a few seconds, without any lengthy startup procedures needed. The flight times of current systems are typically around 1 hour or less due to the limited energy storage capabilities of the used rechargeable batteries. Fuel cells and ultra capacitors are promising alternative energy supply technologies for the future. Technology improvements, mainly based on micro- and nanotechnologies, are expected to continue in an evolutionary way to improve the capabilities of future micro- and nano air vehicles, giving improved flight times and payload capabilities.

AVS can be classified into four main typologies depending on their method of propulsion and lift. These are fixed wings, rotary wings, and flapping wings. The fourth class is without propulsion and is called passive. In the followings sections, we will briefly review one or more examples from each class, and analyze their main advantages and disadvantages.

Among the different typologies of AVS, fixed wing is the most developed and the easiest to design and build. These kinds of vehicles require relative high speed for flight, typically 6 to 20m/s. As they are incapable to hover or fly any slower, indoor flight is very challenging and is often avoided. Examples of suitable applications are location of forest fires, searching for people at sea, and missions where low speed is not required.

The second type of MAV typology are systems with rotary wings. These AVS basically have the same structure as macroscale helicopters and, thus, are able to fly at quite high speeds, hover, and execute vertical take-off and landing (VTOL). These features make them perfect for indoor flight and short-range reconnaissance. Due to larger power requirement for hovering and VTOL, the endurance is also the bottleneck for this kind of AVS. With the miniaturization, a lot of challenges arise. Examples are low efficiency of the rotor system and the low thrust-to-weigh ratio. Despite these disadvantages, rotary AVS are the only configuration capable to combine acceptable high and low speed characteristic including hovering. Despite that this configuration is the most common for larger aircrafts, it suffers from the disadvantage that it is difficult to control with respect to the quad-rotors configuration.

Both fixed wings and rotary wings provide mature and well-know technologies, but have problems due to the high unsteady effects due to reduction of Reynolds numbers. This motivated researchers to investigate alternative typologies. The basic idea was adapted from nature and uses the same flying technique as insects and birds: flapping wings. In fact, the principal motivation seems to be the possibility to integrate lift and thrust together with stability and control mechanism. However, when we refer to this class of vehicles, we should make a distinction between birdlike vehicles called ornithopters and insect-like vehicles called entomopters. These two subclasses of flapping wings have completely different features. Ornithopters, like the majority of birds, generate lift by flapping wings up and down with synchronized small variations of angle of incidence. This method of thrust generation require forward flight similar to fixed-wing AVS. As a result, ornithopters cannot hover, and they need to obtain an initial airspeed before taking off. Entomopters use the kinematics of insects for flying, meaning a large and rapid change of angle of incidence.

Due to this large angle variation between the upstroke and downstroke, this technique is sometimes also referred to as pitch reversal. Compared to how birds fly, they are able to generate much more lift and, thus, are able to execute VTOL and hovering. With these two advantages, entomopters are much more interesting to adapt to AVS than ornithopters. Insects generate wing beats by contraction of muscles. The muscles can either generate wing motion through direct attachment or through indirect attachment, where the wing motion is generated, for example, through deforming the shape of the thorax. Large insects with lower beat frequency use both these modes of flying while smaller insect use mainly indirect muscles.

Considering the short-term future rotary-wing NAV will be the most important commercial type, since it has the best performing technology at present and the near future. Prox Dynamics present a system consisting of two parts: the NAV and the ground control station (GCS). The GCS has three different uses: (1) it will protect the vehicles during the transport, (2) it will be used as remote control system for the NAV in flight, (3) as a station for recharging the AVS batteries. The whole system (NAV+GCS) will have a total weight less than 1 kg, and dimensions of 15 cm× 15cm × 5 cm.

***[Petricca L., Ohlckers P., Grinde Ch. Micro- and Nano-Air Vehicles: State of the Art. February 2011*.]**

Exercises

1. **Look through the text and find out the English equivalents for the following expressions:** система дистанционного управления; парящий

полет; вертикальный взлёт и посадка; рабочий диапазон, прочность; процесс запуска, учитывая, машущее крыло; играть важную роль; движение вверх (вниз); массовое производство; осуществить проверку безопасности; обеспечить жизненно важную информацию; основные особенности.

2. Complete the text with the words from the box:

entomopters	ornithopters	endurance	indoor	outdoor
fixed	operating range	rotary	takeoff weight	flapping

NAVs are defined as small air vehicles with an … less than 1 km, a maximum flight altitude around 100 m, … less than one hour, and maximum … (MTOW) of 25 g while MAVs are defined as 5 kg MTOW with endurance around 1 hour and an operative range around 10 km.

AVS are capable to perform both … missions and … missions in very challenging environments. The main applications are intelligence, surveillance, and reconnaissance missions. Furthermore, NAVs, thanks to their reduced dimensions, are perfect for … inside buildings, providing a very useful tactical advantage.

AVS can be classified into four main typologies depending on their method of propulsion and lift. These are … wings, … wings, and … wings. The two subclasses of flapping wings have completely different features. …, like the majority of birds, generate lift by flapping wings up and down with synchronized small variations of angle of incidence. … use the kinematics of insects for flying, meaning a large and rapid change of angle of incidence.

3. Match the words from the text (1-6) with their definitions (A-F). Translate the words:

1	ornithopter	A	considering
2	entomopter	B	a stroke made upward
3	with respect to	C	an airfoil that rotates in an approximately horizontal plane
4	rotary wing	D	birdlike vehicle
5	reconnaissance	E	insect-like vehicle
6	upstroke	F	intelligence

4. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

provide	from the disadvantage
execute	a rapid overview
suffer	a safety check
play	vital information

do	control system
main	vertical take-off and landing
remote	an important role
mass	features
due to	advantages
perform	production
analyze	useful operations

5. Which words on the left have an opposite meaning to those on the right?

1	upstroke	A	disadvantage
2	advantage	B	rotary
3	indoor	C	decrease
4	fixed	D	downstroke
5	useful	E	outdoor
6	increase	F	useless

6. Complete each sentence (1-6) with one of the endings (A-F):

1	These systems can provide a rapid overview in the area around the personnel,	A	is that they have to be ready for flight in a few seconds, without any lengthy startup procedures needed.
2	Despite that this configuration is the most common for larger aircrafts,	B	B are expected to continue in an evolutionary way to improve the capabilities of future micro- and nano air vehicles, giving improved flight times and payload capabilities.
3	One of the main features that NAVs must have	C	are able to fly at quite high speeds, hover, and execute vertical take-off and landing
4	Technology improvements, mainly based on micro- and nanotechnologies,	D	without exposing them to danger.
5	Many research institutions are actively studying and developing new air vehicles,.	E	it suffers from the disadvantage that it is difficult to control with respect to the quad-rotors configuration.
6	These AVS basically have the same structure as macroscale helicopters and, thus,	F	reducing size and weight while improving performance, and adding more functionality

7. **Grammar.**
Complete the text with one word from the list in each space. Mind the use of highlighted language in the text. Translate the next sentences into Russian:

would	can	are able	could
	should	must	have to

1. Furthermore, flight duration … be 20 to 60 minutes.
2. These systems … provide a rapid overview in the area around the personnel.
3. Some of the applications described above … be extended to the civilian field. For example, the police and the fire brigade … use the capability of indoor flights for inspecting unsafe or collapsed buildings.
4. One of the main features that NAVs … have is that they … to be ready for flight in a few seconds, without any lengthy startup procedures needed.
5. Compared to how birds fly, they … to generate much more lift and, thus, … to execute VTOL and hovering.
6. Since AVS … decrease the time necessary to explore a given area, they … be used in disaster cases, such as earthquakes, after hurricanes, or in collapsed mines.

UNIT 5. KNOWLEDGE-BASED SHAPE OPTIMIZATION OF MORPHING WING FOR MORE EFFICIENT AIRCRAFT

The very challenging targets of new environmental requirements for transport aircraft force the researchers to look for more advanced aircraft configurations, based on more efficient aerodynamics and structures together with more sophisticated flight control systems.

The Breguet range equation combines aerodynamic, propulsion, and structural figures of merit and suggests acting on both the aircraft empty weight and the lift over drag ratio, in order to improve the modern aircraft efficiency. Many are the approaches investigated during recent years trying to improve all the Breguet equation terms, such as advanced and unconventional configurations, able to improve aircraft efficiency, new materials and structural concepts, active controls to peak loads reduction and flight control improvements, more efficient engines, and alternative fuels. Certainly morphing technologies offer potential benefits for a more efficient aircraft but a clear evaluation of their real benefits is not available yet. One of the key challenges for morphing technologies is represented by the identification of the most suitable actuation concept able to reduce the actuation energy and the mechanism weight.

While current aircraft are already equipped with systems able to introduce in-flight geometrical variations such as wing area change, variable camber, and retractable landing gear, the morphing of next generation still has challenges and leads to the design of morphing wings based on conformable control surfaces. In particular, the variable wing camber morphing, considered as the capability to change the airfoil shape without surface discontinuities often based on the adoption of ad hoc designed flexible skins, appears as an efficient way to maximize the lift over drag ratio and to reduce the fuel consumption over the entire flight envelope.

However, the design of this kind of morphing devices requires developing specific procedures able to assist the engineers during both the design and the benefits evaluation phases. Currently, this target is commonly addressed by means of dedicated multilevel and multi objective optimization procedures. Multilevel capabilities allow performing the optimization of morphing shapes and the design of the morphing mechanism separately; multi objective techniques help to design aircraft able to adapt its shape to optimize the performances along the cruise or at a wide range of different flight conditions.

The design of morphing wing devices must combine two opposite requirements, often named kinematic and structural requirements, respectively: a flexible structure so to minimize the energy necessary to adapt its shape as expected and at the same time an enough rigid structure able to maintain the new shape under the aerodynamic loads when the morphing mechanism is not actuated. The approach is based on the optimization of aerodynamic, stiffness, and actuation sequentially, passing through the definition of a family of optimal morphing shapes associated with a group of as many flight conditions. Hence, the design of morphing mechanism depends on the availability of the optimal shapes that must be achieved when it is actuated and that are computed before the mechanism is known. In this way the optimal shapes guarantee the aerodynamic performances, while the mechanism can be optimized considering both kinematic and structural requirements.

The key problem is that the allowable shape variation laws depend on the type of mechanism, while the mechanism design depends on the shape changes that the mechanism must be able to reach. For this reason, in recent years many efforts have been made aiming at considering energy and actuation requirements as well as structural constraints, directly during the aerodynamic shape optimization. The work presented in this paper focuses on the first level of a wider morphing design framework having the following capabilities: wing shape optimization able to combine aerodynamic performances with optimal deformation of the skins (first level); optimal design of compliant mechanism able to produce, once actuated, the optimal shape coming out from the first level (second level); integration of the morphing devices into a high-fidelity model representing the complete aircraft for final aeroelastic assessment to evaluate the reliability of the designed morphing solutions.

Initially, the first level was implemented as a simple 2D shape optimization linked to a viscous and subsonic 2D aerodynamic solver, while the second one represented a general code for the synthesis of compliant mechanisms and two software pieces have been developed separately. Recently, the first one has been extended in order to produce 3D wing models starting from the results which continued to be obtained by 2D shape optimization while the second one has been improved by adding multiobjective capabilities The paper describes the novel progress beyond this point about the first level optimization which is now based on a comprehensive knowledge-based engineering (KBE) framework able to define the optimal morphing wing shape in terms of mission profile performances, directly in the three-dimensional space. It is based on coupling a parametric geometry representation, able to predict the structural response of morphing skin, with Computer-Aided Engineering (CAE) capabilities, Object-Oriented Programming (OOP), genetic algorithm, and aerodynamic analyses.

The results obtained applying it to a Reference Aircraft (RA), coming from the FP7 EU NOVEMOR project (Novel Air Vehicle Configurations: from Fluttering Wings to Morphing Flight) and adopted as a benchmark to evaluate the optimal benefits that can bring in terms of global performances, are reported to validate the proposed procedure and to evaluate the impact of continuous chordwise and spanwise camber variation in terms of lift to drag ratio and aerodynamic load distribution. Morphing seems a potentially promising technology allowing matching the new stringent requirements in terms of environmental impact of next generation aircraft.

Unfortunately the lack of design procedures specifically dedicated to the optimal design of morphing mechanisms appears clearly. Indeed, the so-called knowledge-based shape optimization procedure has been introduced and described that is able to combine aerodynamic with structural performances, mainly related to the behavior of the skin during the shape variation. The proposed procedure has been evaluated in the design of morphing wing based on conformable leading and trailing edge surfaces able to adapt the wing camber during the mission profile.

An external optimization loop works on the most important design variables that affect the camber morphing and it is dedicated to the aerodynamic performance evaluation. A nested loop, based on a particular development of CST method, guarantees that the outer loop works only on feasible shapes able to satisfy wing-box volume constraints and morphing skin requirements. Some examples are reported, concerning the so-called Reference Aircraft, a regional-type aircraft developed inside NOVEMOR project and used as a test bench for a final assessment on morphing applications. The results obtained for the leading edge device at the subsonic regime and the trailing edge device at the transonic flight regime have been selected and the mission analyses have been completed to quantify possible benefits in terms of fuel saving.

During these studies, only the aerodynamic behaviour and the structural behaviour of the morphing skin were considered. Neither the impact on the maximum takeoff weight of the morphing mechanisms nor the effect of aeroelasticity on the behavior of morphing devices has been considered. A family of optimal shapes have been produced and verified using both medium and high-fidelity tools showing promising results as well proving the versatility of the proposed approach. During the second level of the same procedure, all the optimal shapes can be adopted as multiple targets for the optimal design of the morphing mechanism, according to the multiobjective design strategy.

[De Gaspari A., Ricci S. Knowledge-Based Shape Optimization of Morphing Wing for More Efficient Aircraft. August 2015.]

Exercises

1. Look through the text and find out the English equivalents for the following expressions: формула дальности Бреге; собственная масса; кривизна крыла; коэффициент лобового сопротивления; взлётный вес; внешний контур; носок крыла; задняя кромка крыла; убирающееся шасси; экономия топлива; максимально сократить вес; аэродинамические характеристики, многосторонний подход, предоставлять потенциальные преимущества, оценить влияние, полифункциональность (подхода).

2. Complete the text with the words from the box:

leading	chordwise	fuel saving	spanwise	versatility
mission	trailing	camber	morphing (2)	takeoff

1. **…** seems a potentially promising technology allowing matching the new stringent requirements in terms of environmental impact of next generation aircraft.
2. The so-called knowledge-based shape optimization procedure has been evaluated in the design of morphing wing based on conformable … and … edge surfaces able to adapt the wing … during the … profile.
3. The results are reported to validate the proposed procedure and to evaluate the impact of continuous … and … camber variation in terms of lift to drag ratio and aerodynamic load distribution.
4. An external optimization loop works on the most important design variables that affect the … morphing and it is dedicated to the aerodynamic performance evaluation. The results obtained for the … edge device at the subsonic flight regime and the … edge device at the transonic flight regime have been selected and the mission analyses have been completed to quantify possible benefits in terms of … .
5. During these studies, only the aerodynamic behaviour and the structural behaviour of the morphing skin were considered. Neither the impact on the maximum … weight of the … mechanisms nor the effect of aeroelasticity on the behavior of … devices has been considered.
6. A family of optimal shapes have been produced and verified using both medium and high-fidelity tools showing promising results as well proving the … of the proposed approach.

3. Match the words from the text (1-5) with their definitions (A-E). Translate the words:

1	landing gear	A	the rear edge of a moving body, especially an aircraft wing or propeller blade
2	leading edge	B	aiming at multiple targets
3	multiobjective	C	the power that moves something in a forward
4	camber	D	the foremost edge of an aerofoil, especially a wing or propeller blade
5	propulsion	E	curvature

4. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

retractable	loads reduction
fuel	weight
to peak	edge
takeoff	landing gear
empty	saving
leading	camber
trailing	skin
wing	applications
variable	surface
morphing	shape
trailing edge	mechanism

5. Which words on the left have a similar meaning to those on the right?

1	outer loop	A	complex
2	sophisticated	B	with the help of
3	benefit	C	exact
4	stringent	D	multifunctionality
5	by means	E	outside loop
6	versatility	F	advantage

6. Complete each sentence (1-6) with one of the endings (A-F):

1 The very challenging targets of new environmental requirements for transport aircraft force the researchers	A	able to improve aircraft efficiency, new materials and structural concepts, active controls to peak loads reduction and flight control improvements, more efficient engines, and alternative fuels
2 Many are the approaches investigated during recent years	B	allowing matching the new stringent requirements in terms of environmental impact of next generation aircraft.
3 Multilevel capabilities allow performing the optimization of morphing shapes and the design of the morphing mechanism separately;	C	to look for more advanced aircraft configurations, based on more efficient aerodynamics and structures together with more sophisticated flight control systems.
4 Morphing seems a potentially promising technology	D	multi objective techniques help to design aircraft able to adapt its shape to optimize the performances along the cruise or at a wide range of different flight conditions
5 The results obtained for the leading edge device at the subsonic regime and the trailing edge device at the transonic flight regime	E	showing promising results as well proving the versatility of the proposed approach

6 A family of optimal shapes have been produced and verified using both medium and high-fidelity tools	F	have been selected and the mission analyses have been completed to quantify possible benefits in terms of fuel saving.

7. Grammar.

Complete the text with one word from the list in each space. Mind the use of Participle in the text. Translate the next sentences into Russian:

showing	using	considering	allowing	having
promising	aiming	proving	coupling	coming out

1. In recent years many efforts have been made … at … energy and actuation requirements as well as structural constraints, directly during the aerodynamic shape optimization.
2. The work presented in this paper focuses on the first level of a wider morphing design framework … the following capabilities: wing shape optimization able to combine aerodynamic performances with optimal deformation of the skins (first level); optimal design of compliant mechanism able to produce the optimal shape … from the first level (second level); integration of the morphing devices into a high-fidelity model representing the complete aircraft for final aeroelastic assessment.
3. Morphing seems a potentially … technology … matching the new stringent requirements in terms of environmental impact of next generation aircraft.
4. A family of optimal shapes have been produced and verified … both medium and high-fidelity tools … promising results as well … the versatility of the proposed approach.
5. It is based on … a parametric geometry representation, able to predict the structural response of morphing skin.

UNIT 6.
MODELING TECHNIQUES FOR A COMPUTATIONAL EFFICIENT DYNAMIC TURBOFAN ENGINE MODEL

A dynamic, turbofan engine model was developed in the modeling and simulation environment of Matlab-Simulink. The model has been built without the aid of proprietary data, allowing the tool to be made available to multiple design and research groups. Individual component models developed exclusively in MATLAB/Simulink including the fan, high pressure compressor, combustor, high pressure turbine, low pressure turbine, plenum volumes, and exit nozzle have been combined to investigate the behavior of a turbofan two-stream engine.

Special attention has been paid to the development of transient capabilities throughout the model, increasing physics model, eliminating algebraic constraints, and reducing simulation time through enabling the use of advanced numerical solvers. The lessening of computation time is paramount for conducting future aircraft system-level design trade studies and optimization. The new engine model is simulated for a fuel perturbation and a specified mission while tracking critical parameters. The new approach significantly reduces the simulation time.

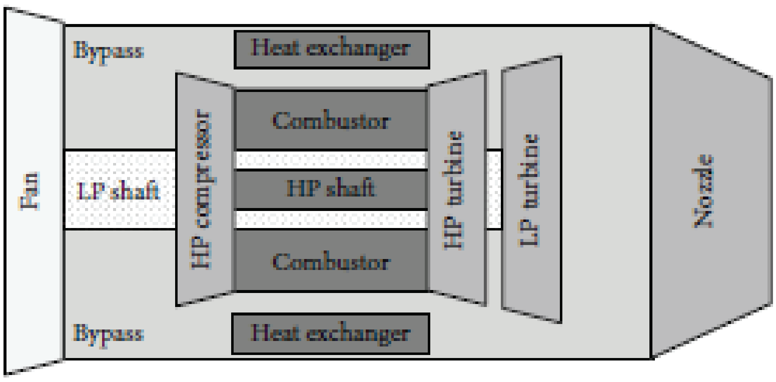

FIGURE 1: Two-stream turbofan engine diagram of major components.

Dynamic models have been developed for real time operation with unsteady effects mass accumulation considered by adding a plenum between each compressor and turbine stage and shaft dynamics. The engine model built in Matlab-Simulink is capable of capturing the shaft dynamics, thermal dynamics, and the unsteady mass flow/plenum volume dynamics. By capturing the unsteady mass flow/plenum volume dynamics, two things were achieved. First, unsteady mass flow and pressure are simulated providing more detail in engine behavior. These perturbations propagate throughout the engine and integrated subsystems that utilize compressor bleed air. Second, the engine model reduces the simulation time of a vehicle level T2Tmodel tool making it feasible to simulate thousands of simulations needed for a complex optimization routine of a large system.

When the engine model was integrated with the full T2T model significant gains in computational efficiency were maintained. The new modeling techniques of incorporating plenum volume dynamics and approximating the compressor maps near the surge line result in a more efficient T2T model. The T2T model with the new engine model will be capable of conducting trade studies and vehicle level design optimization.

Conceptual design groups have traditionally designed aircraft from a subsystem-level viewpoint. Consequently, subsystems such as the propulsion, electrical, and thermal management systems are often optimized without consideration of vehicle level interactions, resulting in a final aircraft design that is not truly optimized. It is believed, however, that vehicle-level analysis of subsystem interactions could result in significant performance gains across the aircraft, potentially improving the overall effectiveness of future platforms. The development of a vehicle level tip-to-tail (T2T) modeling and simulation tool would allow these performance gains to be quantified in a cost effective manner.

Recent work focused on the development of a nonproprietary, thermal T2T aircraft model in Simulink. At least some of the motivation for building a T2T model was to perform design trade studies. In order to run these trade studies effectively and efficiently, computation times should be no slower than real time. The T2T model is intended to stimulate the optimization of individual subsystems for improving overall vehicle-level performance and mitigating the thermal and power challenges of future aircraft platforms. In addition, the nonproprietary nature of the model allows the tool to be distributed to various conceptual design groups and researchers. Specifically, it is foreseen that conceptual designers will use the model to conduct design trade studies, allowing the analysis of multiple design configurations and the resulting subsystem interactions in short time periods.

In order for effective trade studies to be conducted, the model must have relatively fast computation times. Previous work has demonstrated that while effective and accurate, the developed T2T model has extremely large simulation times of half real-time. As a result, the tool would fail to meet a major requirement for conducting valuable design trade studies and optimization in a practical time frame. Through further investigation, it was identified that the turbofan engine model was contributing to slow simulation times. The T2T aircraft model is a stiff system with time constants varying between milliseconds to decaseconds. The turbofan engine has many interfaces with other subsystems and must be compatible with the various time constants captured in the T2Tmodel. Gas turbine engine modeling tools such as Numerical Propulsion System Simulation (NPSS) tool provide a top down propulsion system approach to provide designers with a tool to incorporate the relevant factors which affect propulsion performance early in the design and analysis process.

NPSS was primarily a steady-state tool that has been widely adopted by government and industry over the past decades but has expanded its capabilities in dynamic simulation. NPSS can be expanded to incorporate systems beyond the main engine. The NPSS based models were inefficient when utilized in Matlab-Simulink based T2Tmodel simulations with simulation times 1/6 of real time. Surrogate models were used in the T2T model to reduce computational times.

As previously mentioned, using NPSS models with Simulink is less efficient. The computational inefficiencies reside in the compiling of source code within the Matlab-Simulink framework. These subtle inefficiencies do not pose issues when executing a limited amount of trade studies or simulations but do pose a problem when performing thousands of simulations for an optimization routine. Several techniques were attempted to increase the simulation speed of the turbofan engine model. The turbofan engine model is developed without iteration loops (algebraic constraints) and all states are continuous.

This approach is very important for complex system level simulations of stiff dynamic systems. By modeling all the significant states as continuous states and not steady-state approximations with discontinuities, advanced numerical stiff solvers for stiff systems may be used. Numerical stiff solvers rely on the Jacobian matrix and thus require accurate approximations for gradients of all continuous states. Stiff solvers dramatically reduced the computational time for simulating stiff systems. Also, by having the engine model constructed completely in Simulink, a complete T2T model can be compiled then executed or exported as an efficient executable limiting unnecessary callbacks.

The ability to perform simulations in a timely manner for system level optimization including transient behavior and control architectures provides advanced capability to design highly integrated dynamic systems. The modeling techniques shown here introduce limitations. For example, simulations with the compressors operating near the surge line of the map should be aborted or considered with caution due to the approximations made in the maps to remove iteration loops. The unsteady mass flow/plenum volume dynamics captured by the model are approximated by using large control volumes within the engine components. For more detailed results, the control volumes need to be discreetly divided into smaller control volumes creating a one-dimensional distribution of mass flow and pressure for each of the engine components. This would increase the complexity and simulation time depending on the resolution of the one-dimensional grid of control volumes.

[Rory A. Roberts and Scott M. Eastbourn. Modeling Techniques for a Computational Efficient Dynamic Turbofan Engine Model. October 2014.]

Exercises

1. Look through the text and find the English equivalents for the following expressions: выходное сопло; турбовентиляторный двигатель; двигательная установка; двухконтурный двигатель; воздух, отбираемый от компрессора; граница помпажа; собственные данные; вал; итерационный цикл; получать широкое применение; состоять в; как ранее указывалось; совместимый; способствовать; программа моделирования; с точки зрения; камера сгорания, массовый расход.

2. Complete the text with the words from the box:

fuel perturbation	shaft	two-stream	combustor	compressor bleed
mass flow	exit nozzle	fan	feasible	pressure

Individual component models developed exclusively in MATLAB/Simulink including the … , high pressure compressor, …, high pressure turbine, low pressure turbine, plenum volumes, and … have been combined to investigate the behavior of a turbofan …. engine**.**

The new engine model is simulated for a … and a specified mission while tracking critical parameters. The new approach significantly reduces the simulation time. The engine model built in Matlab-Simulink is capable of capturing the … dynamics, thermal dynamics, and the unsteady …/plenum volume dynamics. By capturing the unsteady mass flow/plenum volume dynamics, two things were achieved. First**,** unsteady mass flow and …are simulated providing more detail in engine behavior. These perturbations propagate throughout the engine and integrated subsystems that utilize … air. Second, the engine model reduces the simulation time of a vehicle level T2Tmodel tool making it … to simulate thousands of simulations needed for a complex optimization routine of a large system.

3. Match the words from the text (1-6) with their definitions (A-F). Translate the words:

1	viewpoint	A	unstable
2	unsteady	B	more important than anything else
3	dramatically	C	tip-to-tail
4	T2T	D	considerably
5	contribute	E	to help to make it successful
6	paramount	F	a particular attitude or way of considering a matter

4. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

high pressure	loops
exit	data
two-stream	system
iteration	compressor
propulsion	engine
proprietary	tool
modeling	nozzle
mass	turbine
turbofan	air
compressor bleed	dynamics
steady-state	flow

5. Which words on the left have a similar meaning to those on the right?

1	feasible	A	because of
2	be widely adopted	B	as a result
3	compatible	C	able to
4	viewpoint	D	stable
5	due to	E	opinion
6	result in	F	consistent
7	capable	G	possible
8	steady	H	receive general acceptance

6. Complete each sentence (1-6) with one of the endings (A-F):

1	The T2T model is intended to stimulate the optimization of individual subsystems	A	provides advanced capability to design highly integrated dynamic systems
2	The ability to perform simulations in a timely manner for system level optimization including transient behavior and control architectures	B	creating a one-dimensional distribution of mass flow and pressure for each of the engine components.
3	For more detailed results, the control volumes need to be discreetly divided into smaller control volumes	C	would allow these performance gains to be quantified in a cost effective manner
4	The T2T aircraft model is a stiff system with time constants	D	for improving overall vehicle-level performance and mitigating the thermal and power challenges of future aircraft platforms
5	The turbofan engine has many interfaces with other subsystems and must be compatible	E	varying between milliseconds to decaseconds
6	The development of a vehicle level tip-to-tail modeling and simulation tool	F	with the various time constants captured in the T2Tmodel.

7. Organizing text.

Complete the text with the words from the box:

it is believed	without consideration	as previously mentioned	consequently	in addition
specifically	from a viewpoint	in order to	result in	as a result

Conceptual design groups have traditionally designed aircraft … subsystem-level … . … , subsystems such as the propulsion, electrical, and thermal management systems are often optimized …of vehicle level interactions, resulting in a final aircraft design that is not truly optimized. …, however, that vehicle-level analysis of subsystem interactions could … significant performance gains across the aircraft, potentially improving the overall effectiveness of future platforms.

Recent work focused on the development of a nonproprietary, thermal T2T aircraft model in Simulink. … run these trade studies effectively and efficiently, computation times should be no slower than real time. …, the nonproprietary nature of the model allows the tool to be distributed to various conceptual design groups and researchers. …, it is foreseen that conceptual designers will use the model to conduct design trade studies.

Previous work has demonstrated that while effective and accurate, the developed T2T model has extremely large simulation times of half real-time. …, the tool would fail to meet a major requirement for conducting valuable design trade studies and optimization in a practical time frame.

The NPSS based models were inefficient when utilized in Matlab-Simulink based T2Tmodel simulations. …, using NPSS models with Simulink is less efficient.

UNIT 7.
EVOLUTION OF THE GAS TURBINE

Through the design experience developed for steam turbines and available to gas turbines, it is not surprising that gas generator compressors, turbines, and power-extraction turbines bear a striking resemblance to each other and to the steam turbine. Nor should it be surprising that the axial flow compressors of today's gas turbines resemble the reaction steam turbine with the flow direction reversed. While many people today recognize the similarities between steam and gas turbine components, most do not fully appreciate the common history these two products share. History tells us that the idea for the gas turbine and the steam turbine were conceived simultaneously. As early as 1791, John Barber's patent for the steam turbine described other fluids or gases as potential energy sources. "John Barber invented what may be considered a gas turbine in which gas was produced from heated coal, mixed with air, compressed and then burnt. This produced a high speed jet that impinged on radial blades on a turbine wheel rim."1 John Barber's ideas, as well as those before him (Giovanni Branca's impulse steam turbine—1629, Leonardo da Vinci's "smoke mill"—1550, and Hero of Alexandria's reaction steam turbine—130 BC) were just ideas. Even though the gas turbines described by these early visionaries would today be more accurately termed 'turboexpanders' (the source of compressed air or gas being a by-product of a separate process), there is no evidence that any of these ideas were ever turned into working hardware until the late 19th Century.

For the next 90 years ideas abounded, but all attempts to produce working hardware were unsuccessful. As Norman Davy stated in 1914, "The theory of the gas turbine was as fully grasped by Barber at the end of the eighteenth century, and by Bresson in the beginning of the nineteenth century, as it is by experts today. The success of the gas turbine as a heat engine rest solely upon practical limitations." However, even in this period of unsuccessful attempts at producing a working prototype, progress was still being made.

• In 1808 John Dumball envisioned a multi-stage turbine. Unfortunately his idea consisted only of moving blades without stationary airfoils to turn the flow into each succeeding stage. Had he realized the need for a stationary stage between each rotating stage he would have originated the concept of an axial flow turbine.

• In Paris in 1837, Bresson's idea was to use a fan to drive pressurized air into a combustion chamber. Here, the air was mixed with fuel gas and burnt. These combustion products were cooled by the addition of more air, and this final product was used to drive turbine blades.

• In 1850, in England, Fernimough suggested a mixed steam and gas turbine, in which air was blown through a coal grate while water was sprayed into the hot gases. The gas and steam mixture then acted to drive a two-bladed rotor.

• *Not until* 1872 did Dr. Franz Stolze combine the ideas of Barber and Dumball to develop the first axial compressor driven by an axial turbine. Due to a lack of funds, he did not build his machine until 1900. Dr. Stolze's design consisted of a multi-stage axial flow compressor, a single combustion chamber, a multistage axial turbine, and a regenerator utilizing exhaust gases to heat the compressor discharge air. This unit was tested between 1900 and 1904, but never ran successfully.

Bresson's ideas are the basis of air cooling (to extend hot gas path part life), Fernimough's ideas are the basis for water injection (for power augmentation and later NOx control), and Stolze's ideas led the way for application of both the present day trends in gas turbine design and the regenerator for improved efficiency.

It was not until 1884 with Sir Charles Parsons' patent for a reaction steam turbine and gas turbine, and 1888, with Charles de Laval's application of Giovanni Branca's idea for an impulse steam turbine did workable hardware emerge. In the 1895/1896 time frame variations in the impulse turbine designs were developed by August C. Rateau, Charles Curtis, and Dr. Zoelly. The experience gained in the development of hardware for steam turbines was directly transferable to gas turbines. At the end of the 19th Century the ideas of the previous centuries were finally being transformed into working hardware.

In 1903, Rene Armengaud and Charles Lemale built and successfully tested a gas turbine using a Rateau rotary compressor and a Curtis velocity compounded steam turbine. Armengaud and Lemale went on to build and test several experimental gas turbines. Originally they used a 25 HP de Laval steam turbine driven by compressed gases from a combustion chamber, which was fed from a compressor. The turbine and compressor ran at 4,000 rpm and, in another early example of steam injection, temperatures were kept down by injecting steam upstream of the turbine nozzle. Even at the turn of the century turbine blade cooling was being integrated into the turbine design as documented in 1914 by N. Davy who wrote, "In the experimental turbine of Armengaud and Lemale the turbine wheel was a double wheel of the Curtis type, water cooled throughout, even the blades themselves being constructed with channels for the passage of the water." Out of necessity (they did not possess the metallurgy to withstand high temperatures) these early pioneers used steam and water injection, and internal air and water cooling to reduce the temperature effects on the combustor, turbine nozzles, and turbine blades.

Later Brown Boveri and Co. went on to build a 500 horsepower gas turbine with a three-stage centrifugal compressor, each stage having 25 impellers in series. This centrifugal compressor, specifically built for a gas turbine application, was modeled from a A.C. Rateau design. It is sometimes difficult to separate, in retrospect, whether these pioneers were augmenting their steam turbines with hot gas, or their gas turbines with steam. But one thing is evident—their ideas are still an important part of today's gas turbine operation.

Throughout most of the first half of the 20th century the development of the gas turbine continued slowly. Advances were hampered primarily by manufacturing capability and the availability of high strength, high temperature resistant materials for use in compressor, turbine, and combustor components. As a result of these limitations compressor pressure ratios, turbine temperatures, and efficiencies were low. To overcome the turbine temperature limits, the injection of steam and water to cool the combustor and turbine materials was used extensively. As N. Davy noted in 1914, "From the purely theoretical valuation of the cycle, the efficiency is lowered by any addition of steam to the gaseous fluid, but in actual practice there is a considerable gain in economy by so doing. Limits of temperature, pressure, and peripheral speed, together with the inefficiencies inherent in pump and turbine, reduce the efficiency of the machine to a degree such that the addition of steam (under the conditions of superheat, inaugurated by its injection into the products of combustion) is of considerable economic value. It is also a great utility in reducing the temperature of the hot gases on the turbine wheel to a limit compatible with the material of which the blades are made." These techniques continue to be used even with today's technology.

[Giampaolo A. Gas turbine handbook: principles and practices, 2006]

Exercises

1. Complete the text with the words from the box:

computer	knowledge	range	coal	advances
components	configurations	operation	values	machine

TECHNICAL IMPROVEMENTS

The growth of the gas turbine in recent years has been brought about most significantly by three factors:

• metallurgical (1) that have made possible the employment of high temperatures in the combustor and turbine (2),

• the cumulative background of aerodynamic and thermodynamic (3), and

• the utilization of (4) technology in the design and simulation of turbine airfoils and combustor and turbine blade cooling (5).

Combining the above has led directly to improvements in compressor design (increases in pressure ratio), combustor design (regenerators, low NOx), turbine design (single crystal blades, cooling), and overall package performance. Gas turbines, which have always been tolerant of a wide (6) of fuels — from liquids to gases, to high and low Btu heating (7) — are now functioning satisfactorily on gasified coal and wood. This is significant considering that (8) is the largest source of energy, at least in the USA. Another contributing factor to the success of the gas turbine is the ability to simplify the control of this highly responsive (9) through the use of computer control technology. Computers not only start, stop, and govern the minute-to-minute (10) of the gas turbine (and its driven equipment) but can also report on the unit's health (diagnostics), and predict future failures (prognostics).

2. Match the words from the text (1-10) with their definitions (A-J):

1	turbine	A	a compressor which consists of two or three compressors which act on the gas one after the other and increase the pressure more each time.
2	compressor	B	the escape of waste gases from the rear of an aircraft or other vehicle.
3	gas compressor	C	something which is produced during the manufacture or processing of another product.
4	exhaust	D	any device which turns round a centre point or axis.
5	multi-stage compressor	E	a pump or machine that increases the pressure of a gas or vapor and decreases its volume.
6	rotor	F	the action or process of making or becoming greater in size or amount
7	Btu	G	abbreviation for British thermal unit(s).
8	by-product	H	an enclosed space inside a turboprop, turbofan or jet engine where the fuel is burnt.
9	combustion chamber	I	a machine for producing continuous power in which a wheel or rotor, typically fitted with vanes, is made to revolve by a fast-moving flow of water, steam, gas, air, or other fluid.
10	augmentation	J	a machine designed to increase the pressure of a gas by using cylinders and pistons or a series of powerful fans.

3. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

energy	nozzle
radial	limitations
pressure	effects
exhaust	hardware
turbine	source
practical	design
theoretical	blades
temperature	gases
working	ratio
power	valuation
moving	augmentation

4. Translate the following terms into English:

1) одноступенчатая турбина;
2) многоступенчатая турбина;
3) активная (газовая) турбина;
4) реактивная турбина;
5) турбина высокого давления;
6) турбина низкого давления;
7) осевая турбина;
8) противоточная турбина;
9) центробежная турбина;
10) трёхкаскадная турбина (с приводом от трёх валов);
11) свободная турбина;
12) свободная силовая турбина;
13) компрессор среднего давления;
14) центробежный компрессор;
15) двухступенчатый центробежный компрессор;
16) одновальный компрессор;
17) однокаскадный компрессор.

5. Complete each sentence (1-10) with one of the endings (A-J):

1	Compressor is used to	A	applying inertial forces to the air (acceleration, deceleration, turning) by means of rotating impellers.
2	The compressor provides the high pressure, high volume air	B	the rotating element.
3	Compressor horsepower is	C	the stationary element.
4	Two types of compressors are in use today—	D	supply air or other gas at increased pressure, e.g. to power a gas turbine.
5	The axial compressor is used	E	which, when heated and expanded through the turbine section, provides the power output required by the process (mechanical drive, generator drive, etc.).
6	The centrifugal compressor is utilized	F	the power that the compressor consumes in compressing the air and moving it into the combustor.
7	The centrifugal compressor, like the axial compressor, is a dynamic machine that achieves compression by	G	they are the axial compressor and the centrifugal compressor.
8	The centrifugal compressor is made up of	H	primarily in medium and high horsepower applications.
9	The impeller is	I	in low horsepower applications.
10	The diffuser is	J	one or more stages, each stage consisting of an impeller and a diffuser.

6. Grammar.

Сочетание «*not until (not till)* + время»

not until – лишь (когда), только; не раньше, чем;
not until much later – лишь значительно позже;
It was not until – 1) только; 2) лишь.

Наличие в одном предложении двух отрицаний *(not + un)* позволяет переводить предложения с этим сочетанием в утвердительной форме с введением слов «лишь» (когда), «только» (после).

Examples:

*1) It was **not until** three centuries later that the state took the responsibilities of education.* — Только три века спустя государство взяло на себя отвественность за образование.

*2) He will **not** return **until** after dark.* — Он не вернётся до темноты.

a) Find out similar word combinations in the text and translate them into Russian; b) Translate the next sentences into Russian:

8. *Not until* Dalton made his famous discovery did scientists realise of this law.

9. The reaction did *not* start *until* the next morning.

10. The theoretical aspects of the phenomenon will *not* be treated *until* later.

11. It is *not until* 1959 that chemists succeeded in obtaining this compound.

12. It was *not until* the Industrial Revolution that metals came to be employed in really vast quantities.

7. The Table is a chronology of key events in the development of the gas turbine as it evolved in conjunction with the steam turbine. Refer to the Table and speak about the history of the gas turbine.

Chronology of the Gas Turbine Development

Data / Name	***Invention***
130BC Hero of Alexandria	Reaction Steam Turbine
1550 Leonardo da Vinci, Italy	Smoke Mill
1629 Giovanni Branca, Italy	Impulse Steam Turbine
1791 John Barber, England	Steam Turbine and Gas Turbine
1831 William Avery, USA	Steam Turbine
1837 M. Bresson	Steam Turbine
1850 Fernimough, England	England Gas Turbine
1872 Dr. Stolze, Germany	Gas Turbine
1884 Charles A. Parsons	Reaction Steam Turbine & Gas Turbine
1888 Charles G.P. de Laval	Impulse Steam Turbine Branca type
1894 Armengaud+Lemale, France	Gas Turbine

1895 George Westinghouse	Steam Turbine Rights
1896 A.C. Rateau, France	Multi Impulse Steam Turbine
1896 Charles Curtis	Velocity Compound Steam Turbine/Gas
1895 Dr. Zoelly, Switzerland	Turbine
1900 F. Stolze, Germany	Multi Impulse Steam Turbine
1901 Charles Lemale	Axial Compressor & Turbine Gas Turbine
1902 Stanford A. Moss, USA	Gas Turbine
1903 A. Elling	Turbo-Charger/Gas Turbine
1903 Armengaud+Lemale	Gas Turbine
1905 Brown Boveri	Gas Turbine
1908 Karavodine	Gas Turbine
1908 Holzwarth	Gas Turbine with deLaval Steam Turbine
1930 Frank Whittle, England	Gas Turbine with Curtis + Rateau Compressor
1938 Brown Boveri—Neuchatel,	Aero Gas Turbine (Jet Engine)
Switzerland	1st Commercial Axial Compressor & Turbine

UNIT 8.
NASA CARGO LAUNCHES TO SPACE STATION ABOARD ORBITAL ATK RESUPPLY MISSION

New hardware that will support dozens of NASA investigations and other science experiments from around the world is among the more than 7,000 pounds of cargo on the way to the International Space Station aboard Orbital ATK's Cygnus spacecraft. It was launched on a United Launch Alliance Atlas V rocket from Space Launch Complex on Cape Canaveral Air Force Station in Florida.

The continued progress was made possible by investment in commercial space. As Orbital ATK's success was celebrated with its fourth cargo resupply mission to the International Space Station, the next milestones of other commercial partners are being looked forward, including commercial crew launches from American soil in the near future. All these missions are critical to the journey to Mars – a journey which has already begun.

The Atlas V launch vehicle lifted off from Cape Canaveral Air Force Station carrying a Cygnus resupply spacecraft to the International Space Station. Liftoff was at 4:44 p.m. EST. Science payloads included experiments that l studied the behavior of gases and liquids and clarified the thermo-physical properties of molten steel; and evaluations of flame-resistant textiles.

The mission was Orbital ATK's fourth cargo delivery flight to the station through NASA's Commercial Resupply Services contract. This was the first flight of an enhanced Cygnus spacecraft to the station. The cargo freighter now features a greater payload capacity, new UltraFlex solar arrays and new fuel tanks. Cygnus' pressurized cargo module has been extended and increases the spacecraft's interior volume capacity by 25 percent, allowing more cargo to be delivered with each mission. It's also the first Cygnus mission using the Atlas V launch system.

Science payloads will support science and research investigations that will occur during the space station's Expeditions, including experiments in biology, biotechnology, physical science and Earth science -- research that impacts life on Earth. Investigations will offer a new life science facility that will support studies on cell cultures, bacteria and other microorganisms, a microsatellite deployer and the first microsatellite that will be deployed from the space station, and experiments that will study the behavior of gases and liquids and clarify the thermo-physical properties of molten steel and evaluations of flame-resistant textiles.

The Space Automated Bioproduct Lab is a new space life science facility that is designed to support a wide variety of fundamental, applied and commercial space life sciences research, as well as education-based investigations for students from kindergarten through university. The facility will support research on microorganisms, such as bacteria, yeast, algae, fungi, and viruses, as well as animal cells and tissues and small plant and animal organisms.

NanoRacks-MicroSat-SIMPL is a modular, hyper integrated satellite designed to provide complete satellite functionality in a nanosatellite scale. It will be the first NanoRacks microsatellite deployed from the space station and the first propulsion-capable satellite deployed from the NanoRacks-MicroSat-Deployer known as Kaber. The commercial deployer system aims to address the growing market of customers wanting to deploy microsatellites in orbit.

The Packed Bed Reactor Experiment studies the behavior of gases and liquids when they flow simultaneously through a column filled with fixed porous media, which is of interest in many chemical and biological processing systems, as well as numerous geophysical applications.

BASS-M (Burning and Suppression of Solids – Milliken) will evaluate flame retardant and resistant textiles as a mode of personal protection from fire-related hazards. Studying flame retardant and resistant behavior of different materials in microgravity will aid in better designs for future textiles and benefit those who wear protective clothing, such as military personnel and civilian workers in the electrical and energy industries.

The Nodes satellites, sponsored by NASA's Space Technology Mission Directorate and developed by the Ames Research Center in Moffett Field, California, consist of two CubeSats weighing 4.5 pounds each and measuring 4 inches by 4 inches by 6.5 inches. They are an example of how technology drives innovation, as they will test new network capabilities for operating swarms of spacecraft in the future.

In addition, Cygnus will deliver replacement cargo items including a set of Microsoft HoloLens devices, a safety jet pack, which astronauts wear during spacewalks known as SAFER, and high pressure nitrogen and oxygen tanks to plug into the station's air supply network.

NASA astronaut Scott Kelly, from his vantage point aboard the International Space Station, photographed the launch of Orbital ATK's Cygnus cargo spacecraft from Cape Canaveral Air Force Station, Florida. Cygnus will be grappled by NASA astronaut Kjell Lindgren, using the space station's Canadarm2 robotic arm to take hold of the spacecraft. Scott Kelly of NASA will support Lindgren in a backup position. The spacecraft will spend more than a month attached to the space station before its destructive re-entry into Earth's atmosphere, disposing of about 3,000 pounds of trash.

The International Space Station is a convergence of science, technology and human innovation that demonstrates new technologies and makes research breakthroughs not possible on Earth. The space station has been continuously occupied since November 2000. In that time, it has been visited by more than 200 people and a variety of international and commercial spacecraft. The space station remains the springboard to NASA's next great leap in exploration, including future missions to an asteroid and Mars.

[*NASA Cargo Launches to Space Station Aboard Orbital ATK Resupply Mission,* 2015]

Exercises

1.Find out the English equivalents for the following expressions in the text: международная космическая станция; детали компьютера (платы, монитор и т.д.); научно-исследовательские достижения; вход в плотные слои атмосферы; космонавт-дублер; грузовой космический корабль; пристыковаться к космической станции; выход в открытый космос**;** система подачи воздуха; запуск космического корабля; управлять массой космического корабля; услуги по доставке грузов; связанные с огнем опасности; развертывание спутников на орбите; оборудование для проведения исследований жизнедеятельности в космосе; усовершенствованный космический корабль; объем полезной нагрузки; герметичный грузовой модуль; полет по доставке грузов на космическую станцию; ракета-носитель; запуск с экипажем на борту; стартовый комплекс; запустить на ракете.

2. Complete the text with the words from the box:

airlines	headquartered	contributing	available	parent
airways	day-to-day	holding	the result of	founded

American Airlines History

.....in 1930, American ....., formerly American ....., was ..... the consolidation of more than 80 small ..... into The Aviation Corporation. American ..... officially became American ..... in 1934, the same year C.R.Smith became president of the company. The ..... began trading on the New York Stock Exchange on June 10, 1939. Originally ..... in New York City, where it continues to maintain a strong presence, American moved its headquarters to Texas in 1979. In 1982, a new holding company, AMR Corporation, was formed and became the ..... company of American .....The formation of AMR had no effect on the ..... operations, but it did provide the company with access to sources of financing that otherwise might not be available. For the next three decades, American became one of the largest ..... in the world, ... nearly $100 billion to the U.S. and international economies. It helped create more than 900000 jobs worldwide and supported approximately 1400 non profit organizations worldwide.

3. Match the words from the text (1-6) with their definitions (A-F). Translate the words:

1	Spacecraft	A	the collection of physical elements that comprise a computer system
2	Missile launch facility	B	a missile, spacecraft, aircraft or other vehicle that obtains thrust from a rocket engine
3	Hardware	C	an artificial object which has been intentionally placed into orbit
4	Rocket	D	a synonym of weightlessness and zero-G, but indicates that g-forces are not quite zero, just very small.
5	Microgravity	E	a vertical cylindrical structure constructed underground for the storage and launching of intercontinental ballistic missiles
6	Satellite	F	A vehicle or machine designed to fly in outer space

4. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

support	provide satellite functionality
occur	a life science facility
deploy	in microgravity
offer	from the space station
designed to	during the space station`s expeditions
study behavior of materials	science and research investigations
fire-related	network capabilities
flame	clothing
test	cargo items
protective	hazards
deliver	retardant

5. Which words on the left have a similar meaning to those on the right?

1	deploy	A	ballistic flight into outer space
2	artificial satellite	B	the carrying capacity of an aircraft or launch vehicle
3	spacewalk	C	a spaceport
4	propulsion	D	a missile, spacecraft, aircraft
5	launch complex	E	sputnik
6	space mission	F	any activity done by an astronaut outside a spacecraft
7	rocket	G	develop
8	payload	H	a means of creating force

6. Complete each sentence (1-6) with one of the endings (A-F):

1 Studying flame retardant and resistant behavior of different materials in microgravity	**A** that will occur during the space station`s expeditions including experiments in biology, biotechnology, physical science and Earth science.
2 The one world alliance is made up of the world`s leading airlines committed to	**B** astronauts wear during spacewalks and high pressure nitrogen and oxygen tanks to plug into the station`s air supply network.
3 Science payloads will support science and research investigations	**C** will aid in better designs for future textiles and benefit those who wear protective clothing in the electrical and energy industries.
4 The experiment studies the behavior of gases and liquids when they flow through a column filled with fixed porous media	**D** that will support studies on cell cultures, bacteria and other microorganisms, a microsatellite deployer and the first microsatellite that will be deployed from the space station.
5 The resupply spacecraft will deliver cargo items including a set of devices for use in NASA`s project, a safety jet pack	**E** providing the highest level of service and convenience to frequent international travelers.
6 Investigations will offer a new life science facility	**F** which is of interest in many chemical and biological processing systems, as well as numerous geophysical applications.

7. Grammar.

Complete the text with one word from the list in each space. Mind the use of Participle and Gerund in the text. Translate the next sentences into Russian:

carrying measuring known packed fixed *designed filled fire-related*
including made continued deployed integrated weighing satisfied

1. NanoRacks is a modular, hyper … satellite … to provide complete satellite functionality in a nanosatellite scale.
2. It will be the first microsatellite … from the space station and the first propulsion-capable satellite … from the Microsat-Deployer … as Kaber.
3. The ….experiment studies the behavior of gases and liquids when they flow through a column … with … porous media, which is of interest in many chemical processing systems.
4. BASS (Burning and Suppression of Solids) will evaluate flame retardant and resistant textiles as a mode of personal protection from … hazards.

5. The Nodes satellites … by NASA and … by the Research Center in California consist of two satellites, … 4.5 pounds and … 4 inches by 4 inches by 6.5 inches.
6. NASA is … with the … progress …possible by investment in commercial
    a. Space.
7. NASA looks forward to the next milestones of other commercial partners, … commercial crew launches from American soil in the near future. The launch vehicle has lifted from Cape Canaveral … a resupply spacecraft to the International Space Station.

UNIT 9.
FALCON 9 LAUNCH VEHICLE

1. Space Exploration Technologies Corporation (SpaceX)

In an era when most technology-based products follow a path of ever-increasing capability and reliability while simultaneously reducing costs, today's launch vehicles are little changed from those of 40 years ago. SpaceX is changing this paradigm with a family of launch vehicles which will ultimately reduce the cost and increase the reliability of access to space.

Established in 2002 by Elon Musk, the founder of PayPal and the Zip2 Corporation, SpaceX has already developed a light lift launch vehicle, the Falcon 1, nearly completed development of the Falcon 9, and developed state of the art testing and launch locations. NASA has selected the SpaceX Falcon 9 launch vehicle and Dragon spacecraft for the International Space Station (ISS) Cargo Resupply Services (CRS) contract award. The contract is for a guaranteed minimum of 20,000 kg to be carried to the International Space Station.

2. Falcon Program Overview

Drawing upon a rich history of prior launch vehicle and engine programs, SpaceX is privately developing the Falcon family of rockets from the ground up, including main and upper-stage engines, the cryogenic tank structure, avionics, guidance & control software and ground support equipment.

With the Falcon 1, Falcon 1e, Falcon 9 and Falcon 9 Heavy launch vehicles, SpaceX is able to offer a full spectrum of light, medium and heavy lift launch capabilities to the customers. SpaceX is able to deliver spacecraft into any inclination and altitude, from low Earth orbit (LEO) to geosynchronous orbit (GEO) to planetary missions. The Falcon 9 and Falcon 9 Heavy are the only US launch vehicles with true engine-out reliability. They are also designed such that all stages are reusable, making them the world's first fully reusable launch vehicles. The Dragon crew and cargo capsule in conjunction with Falcon 9, have been selected by NASA to provide efficient and reliable transport of cargo and potentially crew to the International Space Station (ISS) and other LEO destinations.

3. Falcon 9 Launch Vehicles. Vehicle Overview

Falcon 9 Launch Vehicles are designed to provide breakthrough advances in reliability, cost, and time to launch. The primary design driver is, and will remain, reliability. SpaceX recognizes that nothing is more important than getting a customer's payload safely to its intended destination. The initial flights of the Falcon 9, currently planned in 2009 and 2010, use the Falcon 9 Block 1. Beginning in late 2010/early 2011, SpaceX will begin launching the Falcon 9 Block 2. Block 2 features increased engine thrust, decreased launch vehicle dry mass, and increased propellant load - combined with lessons learned from the flights of the Falcon 9 Block 1. This results in increased mass-to-orbit performance for the Falcon 9 Block 2 when compared with Block 1 performance.

3.1. Structure and Propulsion

Like Falcon 1, Falcon 9 is a two-stage, liquid oxygen (LOX) and rocket grade kerosene (RP-1) powered launch vehicle. It uses the same Merlin engines, structural architecture (with a wider diameter), and launch control system.

The Falcon 9 propellant tank walls and domes are made from an aluminum lithium alloy. SpaceX uses an all friction stir welded tank, the highest strength and most reliable welding technique available. Like Falcon 1, the Falcon 9 interstage, which connects the upper and lower stages, is a carbon fiber aluminum core composite structure. The separation system is a larger version of the pneumatic pushers used on Falcon 1.

Nine SpaceX Merlin engines power the Falcon 9 first stage with 125,000 lbf sea level thrust per engine, for a total thrust on liftoff of just over 1.1 million lbf. After engine start, Falcon 9 is held down until all vehicle systems are verified as functioning normally before release for liftoff.

The second stage tank of Falcon 9 is simply a shorter version of the first stage tank and uses most of the same tooling, material and manufacturing techniques. This results in significant cost savings in vehicle production.

A single Merlin engine powers the Falcon 9 upper stage with an expansion ratio of 117:1 and a nominal burn time of 345 seconds. For added reliability of restart, the engine has dual redundant pyrophoric igniters (TEA-TEB).

The Falcon 9 fairing is 17 ft (5.2 m) in diameter.

3.2. Avionics, Guidance/Navigation/Control, Flight Termination Systems

Falcon 9 vehicle avionics features a single-fault tolerant architecture and has been designed with a view towards human-rating requirements in order to allow future qualification for crewed launch capability. Avionics include rugged flight computers, GPS receivers, inertial measurement units, SpaceX-designed and manufactured controllers for vehicle control (propulsion, valve, pressurization, separation, and payload interfaces), and a C-Band transponder for Range Safety tracking. Falcon 9 transmits telemetry from both the first and second stages, even after separation of the stages. S-band transmitters are used to transmit telemetry and video to the ground.

The guidance and navigation algorithms for Falcon 9 launch vehicles have been heavily influenced by the algorithms used on other launch vehicles, including Falcon 1. The guidance system takes into account the loss of an engine during first stage burn and adjusts the targeted trajectory accordingly. This mix of explicit and perturbation guidance schemes was selected in order to generate a smooth, computationally simple trajectory while maintaining orbital insertion accuracies.

The Falcon 9 launch vehicle is equipped with a standard flight termination system. This system includes two redundant strings of command receiver and encoder, batteries, safe and arm devices, and ordnance in the event of an anomaly in flight.

4. Reliability

The vast majority of launch vehicle failures in the past two decades can be attributed to three causes: engine, avionics and stage separation failures. An analysis by Aerospace Corporation showed that 91% of known failures can be attributed to those subsystems. With this in mind, Falcon 9 launch vehicles are designed for high reliability starting at the architectural level and incorporate the flight-proven design and features of the Falcon 1 launch vehicle.

A major contributor to a reliable system is its operations. To support robust launch operations, the SpaceX launch countdown is fully automated with thousands of checks made prior to vehicle release. After first stage ignition, the vehicle is not released until the first stage engines are confirmed to be operating normally. A safe shutdown is executed, should any off nominal conditions be detected. Falcon 9 benefits from the design and operations concepts established for and proven with the successful Falcon 1 program.

[Falcon 9 Launch Vehicle. Payload User's Guide. R e v 1, 2009]

Exercises

1. Complete the text with the words from the box. Read and translate the text and then speak about the most significant contributors to reliability:

heart	flux	condition	quality	vehicle
opportunity	engine	space	mission	number
stability	part	failure	workhorse	pressure
flight hardware	subsystems	stage	ability	goal
design decisions		full system testing		

SOME OF THE SIGNIFICANT CONTRIBUTORS TO RELIABILITY

1. <u>Robust design margins</u>

Falcon 9 is designed with the goal of carrying humans into (1) aboard the SpaceX Dragon capsule. This (2) drives the initial design of Falcon 9 through the incorporation of increased factors of safety [1.4 versus the traditional 1.25 for uncrewed flight]. The first and second stages are designed to be recovered and reused, and therefore, must have significantly higher *margins* than an *expendable* (3). This also provides a unique (4) to examine recovered hardware and assess design and material selection in order to continually improve Falcon 9.

2. Propulsion and separation event design

The (5) of Falcon 9 propulsion is the Merlin 1C liquid propellant rocket engine. The Merlin (6) features a robust, reliable turbopump design incorporating a single shaft for both the liquid oxygen and fuel pumps, and a gas generator cycle versus the more complex staged combustion. The regeneratively-cooled thrust chamber uses a milled copper alloy liner chamber that provides large margins on heat (7). In addition, the pintle injector was selected for its inherent combustion (8). As a (9) of the launch operations, SpaceX holds the first stage after ignition and monitors engine prior to release to watch engine trends. If an off-nominal (10) exists, an autonomous abort is conducted. This helps prevent an engine performance issue from causing a (11) in flight. Falcon 9 makes use of ten Merlin 1C engines on each vehicle (nine on the first stage, one on the second stage) resulting in high volume engine production, which results in much higher (12) through process control. Flying ten engines on each (13) also builds substantial heritage quickly. Importantly, by employing nine first stage engines, SpaceX debuts the world's first Evolved Expendable Launch Vehicle (EELV)-class launch (14) with engine-out capability through much of first stage flight. With the qualification and first flight units in build and several domestic and international purchased flights currently manifested, Falcon 9 is an ideal (15) for payload customers. SpaceX has also minimized the (16) of stages (two) to minimize separation events. The separation system between the first and second stages does not incorporate electroexplosive devices, instead relying upon a pneumatic release and separation system that allows for acceptance testing of the actual (17). This is not possible with a traditional explosive-based separation system.

3. Failure mode minimization

SpaceX minimized the number of failure modes by minimizing the number of separate (18). The first stage thrust vector control (TVC) system makes use of pressurized rocket-grade kerosene (RP-1).The engine pulls from the high (19) RP-1 side of the pump to power the TVC. This eliminates the separate hydraulic system. In addition it eliminates the failure mode associated with running out of pressurized fluid. Also, the avionics and guidance/navigation/control systems are designed with single fault tolerance, supporting the (20) of Falcon 9 to be human rated.

4. Rigorous testing

In addition to SpaceX's unique (21), Falcon 9 will undergo an exhaustive series of tests from the component to the vehicle system level. This includes component level qualification and workmanship testing, structures load and proof testing, flight system and propulsion subsystem level testing, full first and second stage testing up to (22), including stage static firings at the test and launch sites (as appropriate). In addition to testing environmental extremes (plus margin), all hardware is tested to account for off-nominal conditions.

2. Match the words from the text (1-11) with their definitions (A-K). Translate the words:

1	avionics	A	a navigation system which uses the position of satellites in orbit around the earth (the globe) to detect the exact position of an object on the surface of the earth
2	ignition	B	a material consisting of thin, strong crystalline *filaments* of carbon, used as a strengthening material, especially in resins and ceramics
3	inclination	C	the amount or weight of things or people that an aircraft or spacecraft is carrying
4	liftoff	D	the process of starting the combustion of fuel in the cylinders of an internal-combustion engine
5	launch vehicle	E	having a period of rotation synchronous with that of the earth's rotation
6	carbon fiber	F	the height of an object or point in relation to sea level or ground level
7	payload	G	a rocket-powered vehicle used to send artificial satellites or spacecraft into space
8	altitude	H	a metal made by combining two or more metallic elements, especially to give greater strength or resistance to corrosion
9	geosynchronous	I	the angle at which a straight line or plane is inclined to another
10	alloy	J	(of an aircraft, spacecraft, or rocket) rise from the ground or a launch pad, especially vertically
11	GPS	K	electronics as applied to aviation

3. Mark the halves of the word combinations without looking back at the text. There may be more than one possibility for each.

command	software
launch	ratio
control	missions
geosynchronous	capsule
propellant	vehicle
planetary	mass
cargo	oxygen
dry	system
expansion	orbit
liquid	tank
crew	receiver

4. Find out the next terms in the text. Explain them in English:

1) наддув баков. *Процесс, при котором газ под давлением поступает в баки с топливом для подачи последнего в насосы или камеру сгорания, или для предупреждения испарения или вскипания.*
2) отделение, отрыв. *1. Разделение ступеней многоступенчатых ракет. 2. Явление, заключающееся в том, что пограничный слой потока, обтекающего тело, отрывается от поверхности.*
3) возмущение. *Нарушение в регулярном (правильном) движении небесного тела, как результат воздействия дополнительной силы к тем, которые вызывают регулярное (правильное) движение.*
4) контрольное программное обеспечение, управляющее программное обеспечение; программное обеспечение системы управления.
5) наземное вспомогательное оборудование. *Наземная часть полной системы подготовки, обеспечения и проведения пуска РН – ракеты-носителя.*
6) низкая околоземная орбита. *Околоземные орбиты с высотами до 1000 км.*
7) надёжность. *Свойство изделия выполнять заданные функции, сохраняя свои эксплуатационные показатели в определённых пределах в течение требуемого промежутка времени или требуемой наработки.*
8) капсула. *Небольшая герметизированная кабина с внутренней средой, способной обеспечивать существование человека или иных живых организмов в течение длительного высотного полёта, космического полёта или аварийного спасения.*

5. Which words on the left have a similar meaning to those on the right?

1	increase	A	against
2	conjunction	B	remove
3	include	C	investigate
4	select	D	lower
5	reduce	E	contain
6	trajectory	F	raise
7	versus	G	evaluate
8	eliminate	H	path
9	assess	I	choose
10	examine	J	combination

6. Grammar.

Сочетание «*while (when, if)* + «-ing» или III форма глагола, существительное, прилагательное или предлог»
часто переводится деепричастием или: «при» + существительное

while working – работая, при работе;
while passing – пропуская (проходя), при пропускании (при проходе);
while measuring – в ходе измерения;
when (being) heated – при нагревании (будучи нагрет);

when in use – в процессе, в работе, в действии;
when in a compound – находясь (находящийся в веществе);
when at home – находясь (будучи) дома;
when a liquid – будучи жидкостью;
when free – будучи свободным; в свободном состоянии (положении);
if kept – при хранении;
if finished – будучи законченным.

Examples:

1) ***While discharging*** *the ship (= While we were discharging the ship) we found a few broken cases.* – Разгружая судно (= В то время как мы разгружали судно), мы обнаружили несколько поломанных ящиков.

2) ***When going*** *home (= When I was going home) I met my brother.* – Идя домой (= Когда я шёл домой), я встретил брата.

[В данных случаях в причастных оборотах для выражения обстоятельства времени употребляется *Present Participle.* Такие обороты соответствуют придаточным предложениям времени. В этом случае перед причастным оборотом обычно стоит союз *while* (или *when*), который на русский язык не переводится.]

a) Find out similar word combinations in the text and translate them into Russian; Translate the next sentences into Russian:

1) This must be taken into account *when comparing* data secured in the presence and in the absence of a catalyst.
2) *While agitating* the mixture no temperature rise was observed to take place.
3) *While taking* part in the discussion he advanced his theory.
4) *While (being) treated* for several hours the compound turned dark red.

7. Find nine words connected with launch vehicles in the word search:

A	**E**	**P**	**L**	**A**	**B**	**R**	**J**	**E**	**M**
K	**E**	**R**	**O**	**S**	**E**	**N**	**E**	**S**	**I**
O	**N**	**A**	**V**	**I**	**O**	**N**	**I**	**K**	**S**
I	**G**	**N**	**I**	**T**	**I**	**O**	**N**	**E**	**T**
Y	**I**	**S**	**T**	**A**	**T**	**L**	**P**	**S**	**A**
F	**N**	**A**	**F**	**L**	**I**	**G**	**H**	**T**	**G**
O	**E**	**F**	**O**	**G**	**D**	**U**	**T**	**A**	**E**
R	**G**	**E**	**T**	**A**	**N**	**K**	**N**	**M**	**B**
U	**E**	**T**	**Y**	**P**	**U**	**M**	**P**	**U**	**T**
D	**I**	**Y**	**F**	**R**	**A**	**T**	**A**	**R**	**E**

APPENDIX.
SUPPLEMENTARY READING

AIRCRAFT DESIGN

Modern aircrafts are a complex combination of aerodynamic performance, lightweight durable structures and advanced systems engineering. Many technical challenges need to be balanced for an aircraft to economically achieve its design specification. Aircraft design is a complex and laborious undertaking with a number of factors and details that are required to be checked to obtain optimum the final envisioned product. The design process begins from scratch and involves a number of calculations, logistic planning, design and real world considerations.

Every airplane goes through many changes in design before it is finally built in a factory. These steps between the first ideas for an airplane and the time when it is actually flown make up the design process. Along the way, engineers think about four main areas of aeronautics: Aerodynamics, Propulsion, Structures and Materials, Stability and Control.

Aerodynamics is the study of how air flows around an airplane. In order for an airplane to fly at all, air must flow over and under its wings. The more aerodynamic, or streamlined the airplane is, the less resistance it has against the air. If air can move around the airplane easier, the airplane`s engines have less work to do. This means the engines do not have to be as big or eat up as much fuel which makes the airplane more lightweight and easier to fly. Engineers have to think about what type of airplane they are designing because certain airplanes need to be aerodynamic in certain ways. For example, fighter jets maneuver and turn quickly and fly faster than sound (supersonic flight) over short distances. Most passenger airplanes , on the other hand, fly below the speed of sound (subsonic flight)for lomg periods of time.

Propulsion is the study of what kind of engine and power an airplane needs. An airplane needs to have the right kind of engine for the kind of job that it has. A passenger jet carries many passengers and a lot of heavy cargo over long distances so its engines need to use fuel very efficiently. Engineers are also trying to make airplane engines quieter so they do not bother the passengers onboard or the neighborhoods they are flying over. Another important concern is making the exhaust cleaner and more environmentally friendly/ Just like automobiles, airplane exhaust contains chemicals that can damage the earth`s environment.

Structures and Materials is the sudy how strong the airplane is and what materials will be used to build it. It is really important for an airplane to be as lightweight as possible. The less weight an airplane has, the less work the engines have to do and the farther it can fly. It is tough designing an airplane that is lightweight and strong at the same time. In the past airplanes were usually made out of lightweight metals like aluminium, but today a lot of engineers are thinking about using composites in their designs. Composites look and feel like plastic, but are stronger than most metals. Engineers also need to make sure that airplanes not only fly well, but are also easy to build and maintain.

Stability and Control is the study of how an airplane handles and interacts to pilot input and feed. Pilots in the cockpit have a lot of data to read from the airplane`s computers or displays. Some of this information could include the airplane`s speed, altitude, direction and fuel levels as well as upcoming weather conditions and other instructions from ground control. The pilot needs to be able to process the correct data quickly, to think about what kind of action needs to be taken and to react in an appropriate way. Meanwhile, the airplane should display information to the pilot in an easy-to-read and easy-to-understand way. The controls in the cockpit should be within easy reach and just where the pilot expects them to be. It is also important that the airplane responds quickly and accurately to the pilot`s instructions and maneuvers.

When you look at aircraft, it is easy to observe that they have a number of common features: wings, a tail with vertical and horizontal wing sections, engines to propel them through the air, and a fuselage to carry passengers or cargo. If, however, you take a more critical look beyond the gross features, you also can see subtle, and sometimes not so subtle differences. This is where design comes into play. Each aircraft is built for a specific task and the design is worked around the requirement and need of the aircraft. The design is modeled about the aircraft role and type and not the other way around. This is why airplanes differ from each other and are conceptualized differently. Aircrafts that fall in the same category may have similar specifications and performance parameters, albeit with a few design changes.

Design is a pivotal part of any operation. Without a fixed idea or knowledge of required aircraft, it is not possible to conceive the end product. Airplane design is both an art and a science. In that respect it is difficult to learn by readinga book, rather, it must be experienced and practiced. However, we can offer the following definition and then attempt to explain it. Airplane design is the intellectual engineering process of creating on paper (or on a computer screen) a flying machine to meet certain specifications and requirements establishedby potential users(or as perceived by the manufacturer) and/or pioneer innovative, new ideas and technology. An example of the former is the design of most commercial transports, starting at least with the Douglas DC-1 in 1932, which was designed to meet or exceed various specifications by an airplane company. (The airline was TWA, named Transcontinental and Western Air at that time). An example of the latter is the design of the rocket-powered Bell X-1, the first airplane to exceed the speed of sound in level or climbing flight (October 14, 1947). The design process is indeed an intellectual activity, but a rather special one that is tempered by good intuition developed via experience, by attention paid to successful airplane designs that have been used in the past and by (generally proprietary) design procedures and databases (handbooks, etc.) that are a part of every airplane manufacturer.

[Aircraft Design Project -1. Heavy Business Jet. A project report submitted by Vignesh M., Vincent Kevin Morris Aravind.C. Rajalakshmi Engineering College, Thandalam, Anna University: Chennai 600 025, April 2014.]

DESIGN METHODOLOGY

The start of the design process requires the recognition of a "need". This normally comes from a project brif or a request for proposals (RFP). Such documents may come from various sources:

Established or potential customers

Government defence agencies

Analysis of the market and the corresponding trends from aircraft demand

Develpoment of an existing product (aircraft stretch or engine change).

Exploitation of new technologies and other innovations from research and development.

It is essential to understand at the start of the study where the project originated and to recognize what external factors are influential to the design before the design process is started.

At the end of the design process, the design team will have fully specified their design configuration and released all the drawings to the manufactures. In reality, the design process never ends as the designers have responsibility for the aircraft throughout its operational life. This entails the issue of modifications that are found essential during service and any repairs and maintenance instructions that are necessary to keep the aircraft in an airworthy condition.

The design method to be followed from the start of the project to the nominal end can be considered to fall into three main phases.

The preliminary phase (sometimes called the conceptual design stage) starts with the project brief and ends when the designers have found and refined a feasible baseline design layout. In some industrial organizations, this phase is refers to as the "feasibility study". At the end of the preliminary design phase, a document is produced which contains a summary of the technical and geometric details known about the baseline design. This forms the initial draft of a document that will be subsequently revised to contain a thorough description of the aircraft. This is known as the aircraft "Type Specification".

The next phase (project design) takes the aircraft configuration defined towards the end of the preliminary design phase and involves conducting detailed analysis to improve the technical confidence in the design. Wind tunnel tests and computational fluid dynamic analysis are used to refine the aerodynamic shape of the aircraft. Finite element analysis is used to understand the structural integrity. Stability and control analysis and simulations will be used to appreciate the flying characteristics. Mass and balance estimations will be performed in increasingly fine detail. Operational factors (cost, maintenance and marketing) and manufacturing processes will be investigated to determine what effects these may have on the final design layout. All these investigations will be done so that the company will be able to take a decision to "proceed to manufacture". To do this requires knowledge that the aircraft and its novel features will perform as expected and will be capable of being manufactured in the timescales envisaged. The project design phase ends when either this decision has been taken or when the project is cancelled.

The third phase of the design process (detail design) starts when a decision to build the aircraft has been taken. In this phase, all the details of the aircraft are translated into drawings, manufacturing instructions and supplyrequests (subcontractor agreements and purchase orders). Progressively, throughout this phase, these instructions are released to the manufactures.

Clearly, as the design progresses from the early stages of preliminary design to the detail and manufacturing phases the number of people working on the project increases rapidly. In a large company only a handful of people (perhaps as few as 20) will be involved at the start of the project but towards the end of the manufacturing phase several thousand people may be employed. With this build-up of effort, the expenditure on the project also escalates.

Some researchers have demonstrated graphically the interaction between the cost expended on the project, the knowledge acquired about the design and the resulting reduction in the design freedom as the project matures.

These researchers have argued for a more analytical understanding of the requirement definition phase. They argue that this results in an increased understanding of the effects of design requirements on the overall design process. Understanding these issues will increase design flexibility , albeit at a slight increase in initial expenditure. Such analytical processes are particularly significant in military, multirole, and international projects. In such case, fixing requirements too firmly and too early, when little is known about the effects of such constraints, may have considerable cost implications.

Much of the early work on the project is involved with the guarantee of technical competence and efficiency of the design .This ensures that late changes to the designlayout are avoided or, at best, reduced. Such changes are expensive and may delay the completion of the project, Managers are eager to validate the design to a high degree of confidence during the preliminary and project phases. A natural consequence of this policy is the progressive "freezing" of the design configuration as the project matures.

In the early preliminary design stages any changes can (and are encouraged to) be considered, yet towards the end of the project design phase only minor geometrical and system modifications will be allowed. If the aircraft is not good (well engineered) by this stage then the project and possibly the whole company will be in difficulty.

Within the context described above, the preliminary design phase presents a significant undertaking in the success of the project and ultimately of the company.

Design project work, as taught at most universities, concentrates on the preliminary phase of the design process. The project brief , or request for proposal, is often used to define the design problem. Alternatively, the problem may originate as a design topic in a student competition sponsored by industry, a government agency, or a technical society. Or the design project may be proposed locally by a professor or a team of students. Such design project assignments range

From highly detailed lists of design objectives and performance requirements to rather vague calls for a new and better replacement for existing aircraft. In some cases student teams may even be asked to develop their own design objectives under the guidance of their design professor.

To better reflect the design atmosphere in an industry environment, design classes at most universaties involve teams of students rather than individuals. The use of multi-disciplinary design teams employing students from different engineering disciplines is being encouraged by industry and accreditation agencies.

The preliminary design process presented in this text is appropriate to both the individual and the team design approach although most of the cases involved teams of design students. While, at first thought, it may appear that the team approach to design will reduce the individual workload, this may not be so.

The interpersonal dynamics of working in a team requires extra effort. However, this greatly enhances the design experience and adds team communications, management and interpersonnel interaction to the technical knowledge gained from the project work.

It is normal in team design projects to have all students conduct individual initial assessments of the design requirements , study comparable aircraft, make initial estimates for the size of their aircraft and produce an initial concept sketch.

The full team will then begin its task by examining these individual concepts and assessing their merits as part of their team concept selection process. This will parallel the development of a team management plan and project timeline. At this time, the group will allocate various portions of the conceptual design process to individuals or small groups on the team.

At this point a word needs to be said about the role of the computer in the design process. It is natural that students, whose everyday lives are filled with computer usage for everything from interpersonal communication to the solution of complex engineering problems, should believe that the aircraft design process is one in which they need only to enter the operational requirements into some supercomputer and wait for the final design report to come out of the printer.

Indeed, there are many computer software packages available that claim to be aircraftdesign programs of one sort or another. It is not suprising that students, who have read about new aircraft being designed entirely on the computer in industry, believe that they will be doing the same. They object to wasting time conducting all of the basic analyses and studies and feel that their time would be much better spent searching for a student version of an all-encompassing aircraft design code.

They believe that this must be available from Airbus or Boeing if only theycan find the right person or web address.

While both simple aircraft design codes and massive aerospace industry CAD programs do exist and do play important roles, they have not yet replaced the basic processes. Simple software packages which are often available freely at various locations on the Internet, or with many modern aeronautical engineering texts; can be useful in the specialist design tasks if one understands the assumptions and limitations implicit in their analysis. Many of these are simple computer codes based on the elementary relationships used for aircraft performance, aerodynamics, and stability and control calculations. These have often been coupled to many simplifying assumptions for certain categories of aircraft (often home-built general aviation vehicles). The solutions which can be obtained from many such codes can be obtained more quickly and certainly with a much better understanding of the underlying assumptions, by using directly the well-known relationships on which they are based. In our experience, if students spent half the time they waste searching for a design code (which they expect will provide an instant answer) on thinking and working through the fundamental relationships with which they are already supposedly familiar, they would find themselves much further along in the design process.

The vast and complex design computer programs used in the aerospace industry have not been created to do preliminary work. They are used to streamline the detaildesign part of the process. Such programs are not designed to take the initial project requirements and produce a final design.They are used to take the preliminary design, which has followed the step-by-step processes and turn it into the thousands of detailed CAD drawings needed to develop and manufacture the finished vehicle.

It is the task of the aircraft design students to learn the processes which will take them from first principles and concepts, through the conceptual and preliminary design stages, to the point where they can begin to apply detailed design codes.

At this point in time, it is impossible to envisage how the early part of the design process will ever be replaced by off-the-shelf computer software that will automatically design novel aircraft concepts. Even if this program were available, it is probably not a substitute for working steadily through the design process to gain a fundamental understanding of the intricacies involved in real aircraft design.

[Aircraft Design Projects for engineering students Lloud R. Jenkinson. James F. Marchman III. Butterworth-Heinemann. An imprint of Elsevier Science, Linacre House, Jordan Hill, Oxford OX2 8 DP 200 Wheeler Roud, Burlington MA 01803. Copyright 2003, Elsevier Science Ltd. ISBN 0 7506 5772 3.]

Chemical Rocket Propulsion

Recently, an important milestone has been reached in the history of chemical rocket propulsion, with the retirement of the Space Shuttle. The end of one era brings the dawn of a new era in space transportation, with the anticipation that, with time, new and better flight vehicles will come on the scene and flourish in their respective applications. Almost surely, those new vehicles will still be propelled in large part by chemical rocket systems, systems that have been updated and improved over those of the previous generation through the efforts of today's researchers and engineers.

Liquid-propellant rocket engines continue as the preeminent chemical rocket propulsion system, from millinewton spacecraft thrusters to meganewton first-stage engines for space launch vehicles. Although it is commonly perceived that liquid rocket engines are a mature technology, there are still many active research areas. For example, replacing highly toxic and expensive-to-handle propellants used in hypergolic systems with greener, less toxic propellants is a current challenge. As the thrust demands go up, achieving longer life for monopropellant systems especially remains an objective.

For missions beyond Earth's orbit, proven relight capability for upper stage engines, and long-term storage for cryogens, will become some of the engineering issues researchers will face. Liquid propulsion will remain a critical component in launch systems in the foreseeable future. In conjunction, the interest in making these systems more reliable, more durable, and less expensive to develop and acquire for a number of diverse flight mission applications will continue, and the engineering challenges associated with these objectives will have to be met.

Solid-propellant rocket motors maintain their importance in meeting the propulsion needs for a number of flight applications, big and small. While solid rockets have had, for a long time now, the reputation as being the cost-effective, ready-to-go option, research continues on improving all aspects of their performance, including their safety and friendliness to the surrounding environment. For example, ammonium dinitramide (ADN) appears to be making inroads as a potential greener replacement for ammonium perchlorate (AP) as an effective oxidizer for a number of solid propellants. There is some interest in going to higher chamber pressures to increase thrust-related performance; at higher pressures, one may encounter the need to more actively inhibit the appearance of combustion instability symptoms during a given motor's operation.

Manned suborbital flights powered by hybrid rocket engines have recently become reality, mainly due to reasons related to low cost and safety. Potential applications of hybrid rockets range from microgravity platforms to launchers and landing vehicles, but researchers must face some challenges, in part due to the peculiar combustion process of hybrid propellants. Different concepts are being studied as a means to increase grain regression rate, from innovative fuels (e.g., paraffin-based solid fuels or solid methane) to innovative engine architectures (e.g., advanced vortex-hybrid or cascaded multistage impinging-jet designs). Other important issues, which must be dealt with, are mixture ratio shifting, combustion efficiency, and combustion instability. Air-breathing rocket engines continue to be a practical propulsion system candidate for some smaller, longer-range, and high-speed missile applications.

Challenges remain moving up in scale and scope, for military and civil applications such as single-stage-to-orbit flight vehicles. International computational and experimental research efforts continue in this regard. Within the aerospace propulsion community, one commonly hears that every significant advance in aerospace transportation has been made possible by a significant advance in propulsion technology. One also hears that, as engineers and scientists, when we are fortunate enough to make significant progress in our time, we do so with the realization that we stand on the shoulders of giants. The giants, of course, are those who paved the way before us, with their insight, perseverance, and skill. This is certainly true of the field of chemical rocket propulsion. With this in mind, one can say, with some confidence, that despite, the inevitable challenges to come, the future of chemical rocket propulsion is bright.

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Condition-Based Maintenance

The drive to reduce aircraft operation and support (O&S) costs, increase platform availability, and enhance their performance and safety has motivated researchers, technology developers, aircraft manufacturers, and fleet operators to explore effective concepts, methodologies, and technologies as an alternative to the traditional schedule-based maintenance philosophy. Condition-based maintenance (CBM), also known as “predictive maintenance,” is a maintenance practice that derives maintenance requirements, in large part, from real time assessment of platform or weapon system condition obtained from embedded sensors and/or external tests and measurements using built-in diagnostic equipment. When coupled with real-time asset data, sophisticated materials, and structural and propulsion models, it promises the delivery of enhanced effectiveness of maintenance programs, preventing unplanned downtime, making better use of maintenance resources, and maximizing the operational life of the asset.

Our analysis indicated that the areas with the highest level of contribution to CBMare sensor technologies, health assessment and analytics (diagnostic and prognostic methods), communications technologies, and decisions support. This issue on CBM addresses all identified areas and focuses on maturing the understanding of the contributing concepts and technologies to achieve a wider implementation of CBM, particularly in the aerospace and defense sectors.

Miller presented the use of a systems’ engineering approach to guide the development of integrated instrumentation/ sensor systems (IISS) and concluded that such approach provides clear benefits in identifying the overall system requirements and architectural framework for categorizing and evaluating alternative architectures. Miller effectively addressed the instrumentation functional features such as interrogation of sensor types, sensors interfaces, multiplexing, and communication to provide flexibility and rapid system reconfiguration to adapt to evolving sensor and data needs.

The proposed novel approach demonstrated the innovation in the design of integrated microelectromechanical- (MEMS-) based multiparameters sensing using carbon nanotube/polyaniline polymer sensors for corrosion sensing and monitoring of aircraft structural materials (e.g., aluminium alloys). Through fusion of the multiparameters sensor data (chloride ion concentration, hydrogen gas evolution, humidity variations, and material degradation), a corrosion index was developed to be used in a condition-based maintenance protocol consisting of both preventative and corrective maintenance scheduling. Due to the criticality of sensor data in the CBM framework, Zhigang et al. presented a meticulous and well-though review of piezoelectric-based acoustic wave generation and detection techniques for structural applications. They reviewed a variety of ingenious ways on how piezoelectric transducers are used in today’s structural health monitoring (SHM) methodologies as a means for generation and/or detection of diagnostic acoustic waves. Although this review presented three different approaches, all-piezoelectric approaches, hybrid approaches, and wireless excitation and detection techniques, these can easily be integrated to provide a more powerful solution to specific problems (e.g., wireless fiber-acoustic approach).

While the above discussed contributions focused on addressing sensor issues for structural applications, L. Jiang and A. Corber presented a thermal fluid dynamics modeling and analysis of a gas turbine engine combustor. This effort is to define the aerothermodynamic working environments and service histories that will enable the assessment of the remaining life of gas turbine critical components, hence significantly reducing the cost and time of gas turbine engine fleet management. Their results illustrated a complicated (uneven distribution) flow features inside a combustor and the need for future improved modeling tools.

Not only key processes, technologies, concepts, and methodologies are critical to the cost-effective implementation of efficient CBM but also decisions support. S. Horning et al. developed and demonstrated an operational readiness simulator for optimizing maintenance activities and operational availability focusing on a rotary wing aircraft. The developed simulator provides a synthetic environment to forecast and assess the ability of a fleet, squadron, or aircraft to achieve the desired flying rates and the capability of the sustainment systems to respond to the resultant demands, while maintaining efficient and optimized maintenance program.

They used this virtual simulator to assess several operational scenarios including adjustment of preventative maintenance schedules, including impact of condition-based maintenance, variation of the annual flying rate, and investigation of deployment options.

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Microturbines

The size of a gas turbine, or its name (heavy industrial, aero-derivative, mini-turbine, microturbine) does not change the fact that all gas turbines are mass flow machines and are thermodynamically the same. To maximize the output power from a gas turbine the tips of its rotors have to turn close to the speed of sound. Therefore, the smaller the diameter of the turbine the higher the speed required to maximize the power output. Aero-derivative and heavy industrial gas turbines generally fall in the 1 megawatt and up range.

The capability of the materials used in a gas turbine is the only limitation it faces. The aero-derivative produces almost as much power as the largest heavy industrial machine. It accomplishes this by running at high rotor speeds (up to 20,000 rpm) to provide the required mass flow.

Microturbines are high-speed (up to approximately 100,000 rpm) combustion gas turbines with outputs from a low of 20 kW to a high of 500 kW. These units evolved from automotive and truck turbocharger components, small

jet engines (in turboprop applications), and auxiliary power units commonly used for ground power for aircraft. Microturbine components typically consist of a centrifugal compressor and radial turbine components mounted on the same shaft, a combustor, and a recuperator. In some designs a separate turbine wheel, the power turbine wheel, is also provided. The recuperator is used to capture exhaust waste heat to heat up compressor discharge air. Heating the compressor discharge air reduces fuel consumption, which reduces NO_x formation and increases the overall efficiency. Microturbines are coupled to alternators or generators (inductive or synchronous generators) for the production of electricity. In mechanical drive applications the microturbine may be coupled to a compressor in refrigeration service or a pump in pumping service. In single and split-shaft microturbine designs the electric generator may be mounted on the same shaft as the compressor and turbine components or a speed-reducing gearbox may be employed between
the gas turbine output shaft and the electric generator (or compressor or pump depending on the application).

Due to the high speeds of the microturbines special attention must be given to the electric generators. These generators are either specifically designed to produce a 60 Hz output or have specialized electronics (rectifiers and converters) to convert the power generated to facilitate utility grid connection.

Microturbines are used in distributed power and combined heat and power applications. With recent advances in electronic, microprocessor based, control systems these units can interface with the commercial power grid and can operate “unattended.”

HARDWARE

The difference between a microturbine and the larger, heavy industrial and aero-derivative, gas turbines is size. While microturbine components are smaller than the multi-megawatt gas turbines, they perform identical functions. That is they follow the laws of thermodynamics and are represented by the Brayton Cycle. In most cases microturbine components are made of the same materials used in larger gas turbines. The primary areas of new development are the combustor and the recuperator.

Compressor

Microturbine compressor components are almost exclusively centrifugal designs. This design type has several advantages: burst speeds are well above even the highest operating speeds, materials are readily available, this component can be precision cast with minimal machining, and some components (derived from small turboprop engines, turbochargers, etc.) are already available. The compressor component, turbine component and in some designs the electric generator rotor are fixed to the main shaft (Elliot Energy Systems TA 100 inertia weld these components onto the main shaft).

Turbine

The majority of microturbines employ the radial inflow turbine wheel design. The design looks much like the compressor component (except of course the geometry is reversed). There are some designs that combine an axial stage (as in multi-megawatt gas turbines) with a radial stage. The selection of turbine wheel design types is primarily a function of parentage (that is, the origin of the microturbine design).

While current turbine wheels are made from the same materials used in the larger gas turbines, development of turbine wheels made from monolithic silicon nitride material (a ceramic) is in progress. These new materials will provide improved high temperature creep rate and oxidation resistance.

When developed these designs and manufacturing techniques will undoubtedly be incorporated into the multi-megawatt gas turbines— just as advances made in jet engine technology was, and continues to be, transferred to the large industrial gas turbine engine designs.

Recuperator

Recuperators transfer heat from the turbine exhaust to the combustor inlet (or compressor discharge). In a recuperator the heat transfer occurs through the passage walls (hot exhaust gases on one side and cool compressor air on the other). Recuperators are essential to achieving increased efficiency from microturbines. Another advantage of recuperators is the reduction in NO_x. This reduction is due to the decrease in the amount of fuel (evidenced as an increase in efficiency) and the subsequent decrease in fuel-bound nitrogen.

The renewed interest in recuperators is extending into the multi-megawatt sizes. Recuperated gas turbines can take advantage of their lower compressor pressure ratios and combustion temperatures to reduce NO_x formation.

High temperature recuperator materials are being developed in order to achieve greater than 40% efficiency at a cost less than $500.00 per kilowatt. These materials are expected to operate between 1290˚F (700˚C) and 1830˚F (1000oC). Among the materials being studied are Alloy 230, Modified Alloy 803, etc.

Combustor

There is no significant difference between microturbine combustors and multi-megawatt gas turbine combustors. Combustors for microturbines, like combustors for larger gas turbines, are either annular or single combustor designs. They are fabricated from martensitic and ferritic iron base alloys or nickel base alloy. The single combustor, which lends itself to the reverse flow design concept, has become the design of choice.

Under development are catalytic combustors. The catalytic combustor promises to achieve emissions below 3 ppm (on natural gas) without the need for exhaust gas treatment.

Controller

Controllers used on microturbines are generally the same as the controllers used on the multi-megawatt gas turbines. In electric generation applications there are some added control tasks. The advent of microturbines and their high-speed generators has necessitated the marriage within the controller of power output conditioning with gas turbine engine control. This controller must not only manage the fuel valve during Start, Stop and Governing sequences, provide machine protection against high vibration, over-speed and over-temperature, but must also condition the high frequency, high voltage power produced by the generator to grid quality.

Also, the controller must be able to communicate with other systems {such as the plant Distributed Control System (DCS), and the Human Machine Interface (HMI)}. Communication protocols such as Modbus®, Ethernet TCP/IP, OPC (Ethernet), DDE (Dynamic Data Exchange), EGD (Ethernet) must be available so that the user/operator can easily interface the control to existing or new plant systems and to maintenance systems.

To achieve suitably fast response the fuel valve must be sized for the microturbine. It is also helpful if the fuel valve can handle two flow paths—one for starting flow (pilot flow) and another for running flow (primary flow).

For power generating applications a power conditioning control must manage load (KW) control, frequency control, synchronizing, load sharing and KW droop.

For mechanical drive applications (compressor or pump drives) the controller must manage suction and discharge pressure & temperature control, bypass or recirculation fl ow control & cooling, surge control (for centrifugal compressors) and miscellaneous plant valves.

Generator

Microturbine manufacturers are currently employing two design variations: high speed single shaft and split shaft. The single shaft type drives the high-speed synchronous (external field coil excitation or permanent magnet) or asynchronous (induction) generator at the same speed as the gas turbine. This generator produces very high frequency AC power that must be converted first to DC power and than to 60 Hz AC power. This is accomplished using a rectifier and an inverter. The inverter rectifies the high frequency AC voltage produced by the alternator into unregulated DC voltage. It then converts the DC voltage into 50 Hz or 60 Hz frequency and 480 volts AC.

With the split shaft design the electric generator is driven by the free power turbine, usually through a speed reduction gearbox, at 3600 rpm. In this design the generator produces 60 Hz power and does not require a rectifier and an inverter.

There are three general types of converters:

- DC Link Converter
- High Frequency Link Converter
- Cycloconverter

Bearings

Because operating conditions are very demanding at the high rotational speed (up to 100,000 rpm), bearings are a critical component of the microturbine. Conventional hydrodynamic and anti-friction bearings, employing a pressurized lube oil system (including a pump and an oil cooler) are still employed by some manufacturers. However, advances have been made into the use of "air," "gas" of "film" bearings.

This type of bearing uses a thin fi lm of pressurized air to support the shaft. Fluid fi lm bearings utilize a thin fi lm of air between the rotating shaft and the stationary housing and this fi lm transfers the forces from one to the other. The fluid film is accomplished by delivering airflow through the bearing compartment. One design technique creates the air fi lm with an orifice. Another design technique delivers the air through a porous medium thereby ensuring uniform pressure across the entire bearing area.

The result is that air bearings provide a frictionless load-bearing interface between surfaces that would otherwise be in contact with each other. Since air bearings are non-contact, they avoid the traditional bearing-related problems of friction, wear, and the need for a lubricant. While this is a reliable design guideline for air bearings, lower air pressures, increased damping, increased stability and increased stiffness are all improved with increased surface area.

A refinement of the air bearing design is the "foil" bearing. In a "foil" bearing design, when the shaft is stationary there is a small preload between the shaft and the bearing caused by the foils. When the shaft starts to turn, hydrodynamic pressure builds up that pushes the foil away from the shaft causing the shaft to become airborne.

Another particular bearing design can be described as follows:

Water or water vapor discharged through ultra-fi ne porous medium isused as the working fluid. The bearing surface is virtually hydraulically smooth. The bearing is enclosed by the water storage, and the water pressure is controlled so as to be higher than the atmospheric pressure. At rest the clearance is filled with liquid water. As the speed of rotation increases a phase change occurs through viscous dissipation and heat transfer from the high-temperature journal to the bearing surface converting the "liquid water" to "water vapor." Water vapor evaporation from the bearing surface elevates local pressure in the bearing clearance area; this stabilizing effect due to "hydrostatic" pressure is than superimposed on the conventional stabilization due to "hydrodynamic" pressure.

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