

The global APU fleet totals 21,200 units. Maintenance, repair and overhaul of APUs is a specialised business. The majority of the repair and overhaul market is limited to a few dozen shops. These are listed.

Global APU repair & overhaul shop survey

Auxiliary power units (APUs) account for 13% of component MRO costs, behind only wheels and brakes at 17% and avionics at 15%. These figures come from the latest AeroStrategy Global MRO Market Economic Assessment for the Aeronautical Repair Station Association (ARSA). This assessment observes that the same three component types are the least labour-intensive to repair and overhaul.

The overhaul process for APUs is similar to that for main engines, starting with cleaning and inspection. Main repair processes are heat and surface treatment, machining and hand finishing, while accessories such as fuel nozzles, fans, oil pumps and actuators are subject to their own repair and testing processes.

Labour accounts for about 25% of the cost of APU repair and overhaul, while another two thirds is the cost of material, and the balance of 10% goes on outside services. As the ARSA study points out, OEMs generally prefer to maximise use of their own material and parts, while independents may be more motivated to minimise what they buy from the manufacturer and develop their own repairs using FAA designated engineering representative (DER) authority or, under EASA, design organisation approval (DOA).

Repairing rather than replacing blades, for example, is usually a more economical option for the customer if the repair is feasible, as well as a more attractive option for the maintainer. To address the pronounced signs of wear caused by hard particle erosion and commonly exhibited by APS 3200 guide vanes after an average of about 4,000 APU operating hours, Lufthansa Technik resorted to reverse engineering.

Classic repairs such as overlay welds impair the metallurgical properties of the

blades in a critical area, and the DER/DOA demands that a repaired part should correspond to a new part in respect of form, fit and function. LHT embarked on what it says was an effort-intensive process that started with laser measurement of a group of parts to establish their geometry. Then the defective blade is removed from the shaft and replaced by a cylindrical repair blank using a parameter-controlled welding process. The weld flash is removed and a four-axis milling machine is used to produce the final blade contour. The repaired product is at least as good as new and the cost, says LHT, is more than competitive.

The APU itself originated as a way of enabling jet aircraft such as the 727 to operate from airports that were not equipped to start the new turbine engines using ground power. In its current implementation, APUs are still used to start the engines, but they also commonly provide bleed air for the air conditioning system and electrical power for aircraft systems before the main engines are started or after they are shut down.

The development of extended range twin-engine operations (ETOPS) by twin-engined aircraft made the APU a more critical item of equipment. To support ETOPS they must often be certified to start and operate in flight up to the operational ceiling of the host aircraft. Engine and APU oil levels and consumption rates have to be checked before any ETOPS flight, and if the APU is required it must be included in the engine oil consumption programme required by the regulations.

APU market

The newest APU in commercial service, the Pratt & Whitney Canada PW980A that starts the Airbus A380's

engines, is also the biggest. Rated at more than 1,800 hp and derived from the 747-400's PW901A, it was actually designed by integrated product teams formed by Hamilton Sundstrand Power Systems and P&WC along with Airbus.

Since the consolidation of the two United Technologies subsidiaries' APU businesses in 2002, Hamilton Sundstrand has been responsible for marketing, customer support and aftermarket services on both units. One PW908 customer is Singapore Airlines, which has signed a 17-year support agreement covering the APUs on its 19 aircraft. There were just a couple of dozen A380s in service by the end of 2009, but the PW901 fleet numbered a still impressive 677. The PW901A itself displaced the Honeywell GTCP660 that had equipped earlier variants of the 747: there are still 340 of the 660 model in service on 747 Classics.

All told, according to ACAS, there were 21,219 APUs equipping regional jets (RJs) and larger air transport aircraft in service by December 2009 (*see table, page 40 & 42*). Apart from the two P&WC types, the remainder are all products of Honeywell or Hamilton Sundstrand, and fully 23% of the total are accounted for by Honeywell's GTCP131-9 series.

The 4,960 GTCP131-9s in service include just over 3,000 -9Bs on 737 NGs, 1,859 -9As on the four single-aisle Airbus variants and another 111 -9Ds on MD-90s. With a two-stage axial turbine for increased life, it was designed so that any line replaceable unit (LRU) can be removed and field replaced within 15 minutes.

The GTCP131-9A was certified in April 1998 and entered service later that year. It replaced the GTCP36-300K that survives on more than 500 earlier models, mainly A320s, but including over 100

SUMMARY OF GLOBAL ACTIVE APU FLEET - PART ONE

APU Model Series	Aircraft Model Series	Number of aircraft / APU	APU Model Series Total
APS2100	717-200	155	155
APS2000	737-300	183	386
	737-400	71	
	737-500	132	
APS3200	A318-100	43	1,548
	A319-100	447	
	A320-100	8	
	A320-200	750	
	A321-100	45	
APS2300	A321-200	255	589
	170-100LR	153	
	170-100SL	14	
	175	1	
	175-200AR	39	
	175-200LR	85	
	190 Lineage	1	
	190-100	2	
	190-100AR	173	
	190-100LR	74	
	195-100	1	
	195-200AR	12	
195-200LR	34		
GTCP85-98	727-100	155	1,892
	727-200	594	
	DC-8-50	2	
	DC-8-70	3	
	DC-9-10	55	
	DC-9-20	3	
	DC-9-30	311	
	DC-9-40	42	
	DC-9-50	60	
	DC-9-80 (MD-80)	631	
	MD-88	36	
GTCP85-115	1-11-200	5	33
	1-11-400	13	
	1-11-475	7	
	1-11-500	8	
GTCP85-129	737-100	1	2,078
	737-200	670	
	737-300	832	
	737-400	344	
	737-500	231	
GTCP36-100	146-100	17	51
	146-200	34	
GTCP36-150	146-100	2	1,557
	146-200	24	
	146-300	52	
	146-RJ100	17	
	146-RJ70	6	
	146-RJ85	1	
	328JET-300	110	
	CRJ-100	212	
	CRJ-200	744	
	CRJ-440	86	
	Fokker 100	256	
Fokker 70	47		
GTCP36-280	737-300	17	434
	737-400	51	
	737-500	14	
	DC-9-80 (MD-80)	235	
	MD-88	117	
GTCP36-300	A319-100	107	519
	A320-100	1	
	A320-200	400	
	A321-100	8	
	A321-200	3	
GTCP131-9	737-600	69	4,990
	737-700	1,111	
	737-800	1,724	
	737-900	116	
	A318-100	27	
	A319-100	633	
	A320-200	963	
	A321-100	25	
	A321-200	211	
	MD-90-30	111	

A319s and a handful of A321s. The manufacturer says the -9As average of better than 10,000 hours between unscheduled repair events is 70% better than other APUs in its class size. A claimed 10% power advantage over other APUs enables it to cool or heat cabins in two minutes less, and a de-rate modification is available to reduce fuel consumption by 5%. A derivative of the GTCP131-9 will be used by the Bombardier CSeries, and the engine has demonstrated its ability to operate on biofuel.

Hamilton Sundstrand's APU for Airbus narrowbodies is the APS 3200. Designed specifically for the single-aisle family, it entered service in 1994 and is installed on just under 1,550 aircraft. At 308lbs, it is 46lbs lighter than the Honeywell unit.

The GTCP36 series, meanwhile, includes the 36-150, which serves on more than 1,550 RJs. More than two thirds are on the Bombardier CRJ-100/-200/-400, another 303 on the Fokker 70 and 100, 110 on Fairchild Dornier 328JETs and just over 100 on 146s and Avro RJs. There is also the GTCP36-100, 51 of which equip BAe 146-100s and -200s. More than 430 MD-80s and MD-88s have the GTCP36-280, and 82 737 Classics use the GTCP36-280B.

For the Bombardier CRJ-700/-900/-1000 series, Honeywell developed the RE220. The first general aviation APU to communicate with the aircraft's maintenance data acquisition unit (MDAU), it enables pilots and mechanics to monitor APU performance and trouble-shoot faults from the flightdeck. The RE220 equips 526 CRJs, including the first two -1000s.

Another substantial fleet is the Honeywell GTCP85 series. There are more than 4,500, although that is just a small fraction of the 30,000-plus delivered since the first installation, the first for a commercial aircraft, on a 727 in 1963. In 85-98 form, the engine equips nearly 750 727s, a handful of DC-8s, more than 1,000 DC-9s and 667 MD-80s/-88s. There are still more than 30 of the BAC 1-11's 85-115 model, and more than 2,000 of the 737 Classics' 85-129.

The GTCP331 fleet, used primarily by widebody twins, also exceeds 4,000. The initial 331-200, developed for the Boeing 757 and 767, introduced electronic controls and generates 90kW to support ETOPS back-up power requirements. There are 1,022 in service on the 757-200/-300 and another 897 on 767-200s and -300s. The 331-250 equips just under 400 Airbus A300-600s and more than 200 A310s.

For the Airbus A330 and A340 Honeywell developed the GTCP331-350, which in turn served as the basis for the 767-400's 331-400. There are 636 A330s

SUMMARY OF GLOBAL ACTIVE APU FLEET - PART TWO

APU Model Series	Aircraft Model Series	Number of aircraft / APU	APU Model Series Total
GTCP331-200	757-200	967	1,921
	757-300	55	
	767-200	210	
	767-300	687	
	747-200	2	
GTCP331-250	A300B4-600	184	509
	A300C4-600	3	
	A300F4-600	109	
	A310-200	70	
	A310-300	143	
GTCP331-350	A330-200	359	882
	A330-300	277	
	A340-200	27	
	A340-300	216	
	A340-500	3	
GTCP331-400	767-400	38	38
GTCP331-500	777-200	541	802
	777-300	261	
GTCP331-600	A340-500	26	121
	A340-600	95	
GTCP660	747-100	46	340
	747-200	210	
	747-300	61	
	747-SP	23	
TSCP700-4	DC-10-10	73	396
	DC-10-15	2	
	DC-10-30	108	
	DC-10-40	19	
	MD-11CF	3	
	MD-11ERF	1	
	MD-11ERP	3	
	MD-11F	166	
	MD-11P	21	
TSCP700-5	A300B2	10	103
	A300B4	89	
	A300C4	1	
	A300F4	3	
PW901A	747-400	677	677
PW980A	A380-800	24	24
T-62T-46	146-100	5	278
	146-200	37	
	146-300	7	
	146-RJ100	50	
	146-RJ70	5	
	146-RJ85	84	
	Fokker 50	86	
	Fokker 60	4	
T-62T-40	ERJ-135 Legacy	157	1,071
	ERJ-135ER	34	
	ERJ-135LR	91	
	ERJ-140ER	1	
	ERJ-140LR	74	
	ERJ-145EP	39	
	ERJ-145ER	41	
	ERJ-145EU	39	
	ERJ-145H	4	
	ERJ-145LI	28	
	ERJ-145LR	409	
	ERJ-145LU	6	
	ERJ-145MP	32	
	ERJ-145RS	5	
	ERJ-145SA	6	
ERJ-145XR	105		
RE220	CRJ-700	300	526
	CRJ-900	224	
	CRJ-1000	2	

and 243 A340-200s and -300s with the -350, but just 38 767-400s with the -400. Three A340-500s also have the -350, but the other 26 use the -600 variant, which also equips 95 A340-600s. The other model in the series is the GTCP331-500 used by just over 800 777-200/-300s.

Aboard an earlier generation of widebodies, nearly 500 of Honeywell's TSCP700 series remain in service, including 202 700-4Bs (DC-10), 194 700-4Es (MD-11) and 103 700-5s (A300).

While Honeywell is developing the HGT1700 APU for the A350, the Boeing 787 will use the APS 5000 from Hamilton Sundstrand. After carving out a position in the single-aisle mainliner market with the APS 3200, Hamilton Sundstrand produced the APS 2100 for the 717 and the APS 2300 for the E-170/-190.

Hamilton Sundstrand has delivered more than 600 APS 2300s to more than 50 airlines for the E-170/-190 family, although only 589 were in service by December. There are also 366 of the earlier APS 2000 used by 737 Classics and 155 of the 717's APS 2100.

Finally, the T-62T-40C11 and -40C14 variants of the APS 1000 equip more than 1,070 Embraer RJs in the ERJ-135/-145 series, and the T-62T-46, or APS 1000, provides auxiliary power to 188 146s and RJs and 90 Fokker 50s and 60s.

Overhaul provision

The ARSA Global MRO Market Economic Assessment calculates that the OEMs control around half the APU MRO market, with another 30% shared between independents and airline third party shops and the remaining 20% carried out by airlines in house.

Honeywell's APUs predominate in the market, and its support is correspondingly extensive, with overhaul centres in Raunheim, Germany, and Singapore as well as its home base in Phoenix. Honeywell Aerospace at Raunheim, conveniently close to Frankfurt International, covers Europe, the Middle East and Africa. It services the complete Honeywell range of 20 different models and 41 variants, including those from turboprops and business jets.

KLM and Hamilton Sundstrand established European Pneumatic Component Overhaul & Repair (EPCOR) near Amsterdam Schipol airport in 2000. KLM bought out its joint venture partner in the wake of subsequent market changes. In 2006 Air France KLM decided to make it an APU MRO centre of excellence for the group. The move coincided with the introduction of new APU technology in the parent airlines' fleets, and KLM Engineering & Maintenance established

MAJOR ENGINE SHOPS - ASIA PACIFIC

Engine Shop	APUs Overhauled	Location
AA-MRO	GTCP131-9B	Tulsa, OK, USA
Abu Dhabi Aircraft Technologies	GTCP331	Abu Dhabi, UAE
Air Asia	GTCP85-98/-129 series	Tainan, Taiwan
Aircraft Power & Service	GTCP85/GTCP36 series	Durant, OK, USA
Alitalia Maintenance Systems	GTCP85/GTCP660	Rome Fiumicino, Ital
	GTCP331-200ER series	
	TSCP700	
ANA Engine Services	APS2000/3200	Tokyo Haneda, Japan
	GTCP131/GTCP331/GTCP660	
Aveos	GTCP36-300	Montreal, Canada
Chase Aerospace	GTCP36-100/-150M	Orlando, FL, USA
	GTCP85-98/-115/-129 series	
	GTCP331-200A/-200ER	
	GTCP331-250H	
Delta Tech Ops	GTCP 131-9B/-9D	Atlanta, GA, USA
	GTCP 331-200/-250	
EPCOR	GTCP131-9A/-9B	Amsterdam, Netherlands
	GTCP331-350	
	GTCP331-500	
Finnair Technical Services	APS3200	Helsinki, Finland
	TSCP700-4B/-E	
GMF AeroAsia	GTCP36-4A	Jakarta, Indonesia
	GTCP85-98D	
	GTCP85-129 Series	
	GTCP85-184/185 (not gear box)	
	TSCP700-4B/E	
Hamilton Sundstrand	All Hamilton Sundstrand APUs	San Diego, CA, USA
H+S Aviation	GTCP36-100/150	Portsmouth, U
	GTCP331-200/250	
	PW901A	
	T-62T-46	
Honeywell	All Honeywell APUs	Phoenix, AR, USA
		Raunheim, Germany
		Singapore
		Xiamen, China
		Tel Aviv, Israel
Honeywell TAECO Aerospace (Xiamen)	GTCP85/331 series	
IAI Bedek Aviation	GTCP36/GTCP85	
	GTCP131-9	
	GTCP331/GTCP660	
Iberia Maintenance	GTCP36-300	Madrid, Spain
	GTCP85-98DHF	
	GTCP131-9A	
JAL Engineering	GTCP331	Tokyo Narita, Japan
	GTCP660	
	PW901	
JAT Tehnika	GTCP85-98D/98CK/129E	Belgrade, Serbia
Korean Air	GTCP 660	Bucheon, Korea
Lufthansa Technik	APS2000/3200	Hamburg, Germany
	GTCP85-98*/-129H	
	GTCP131-9A*	
	GTCP331-200*	
	GTCP660-4*	
	PW901	
	TSCP700-4E*	
Lufthansa Technik AERO Alzey	PW901A	Alzey, Germany
PIA Engineering	GTCP85-129K/H	Karachi, Pakistan
	GTCP660-4	
	TSCP700-5	
Piedmont Aviation Component Services	GTCP36-100M/150M/R/RR/RJ/DD	Kernersville, NC, USA
	GTCP85-115C/CK	
	GTCP85-98CK/DCK/D/DCA/DCB/DHF	
	GTCP85-129A/B/C/D/E/F/G/CK/H/J/K	
	GTCP 331-200A/AC/ER/-250E/F/H	
Qantas Engineering & Maintenance	GTCP85 series (13 variants)	Melbourne, Australia
	GTCP331/GTCP660	
	PW901	
Revima APU	APS500/1000/2000/3200	
	GTCP85-98	
	GTCP331-200/-250	
	TSCP700-4/-5	
	PW901/PW908	
Standard Aero	APS2300	Maryville, TN, USA
TAP Maintenance & Engineering Brazil	APS250	
	GTCP85 (series)	
	GTCP36-150A/AA	
	GTCP131-9A/9B	
	GTCP331-200ER	
	GTCP660-4	
	T62-T-40C11	
	TSCP700	
Triumph Air Repair	GTCP85/GTCP131-9B	Phoenix, AR, USA
	GTCP331-200/250	
	GTCP660	
	TSCP700	
	PW901A	
Turkish Technic	APS2000/APS3200	Istanbul, Turkey
	GTCP85-129H	
	GTCP131-9B	
	GTCP331-250H	
	GTCP85-98DHF/C/CK	
United Services	GTCP331-200ER/-500B	San Francisco, CA, USA
	PW901A	
United Turbine Technologies	GTCP85 series	Miami, FL, USA
	GTCP36-100/-150	

the new MRO centre for APUs in partnership with Honeywell. EPCOR's initial focus was on the GTCP131-9B, 331-350 and 331-500 units used by the 737 NG, A330/340 and 777. The company has more recently added 131-9A capability.

Hamilton Sundstrand subsequently formed another joint venture with EADS Sogerma Services: EADS Revima in Normandy, France. It became Revima APU in 2004. Four years later Hamilton Sundstrand bought out its partner's stake. Revima APU overhauls the APUs used by most mainline and regional aircraft, and last year won a contract from Air France Industries KLM Engineering & Maintenance to support the PW901 and TSCP700-4E APUs used respectively by 63 747-400s and 10 MD-11s. The company's repair shop can service a wide range of ATA Chapter 49 LRUs as standalone units. It also maintains a pool of spare APUs for lease and occasionally performs troubleshooting and minor repairs in the field.

Revima APU is also the first repair centre for the A380's PW980 and will carry out warranty work for all A380 operators. Last year P&WC appointed Aviall as global spares distributor for the PW901.

H+S Aviation in the UK is an independent PW901 shop and one of relatively few independents in Europe. It also handles the Honeywell GTCP36-100/-150 and GTCP331-200/-250. The other European PW901 shop is Lufthansa Technik's AERO Alzey subsidiary. Lufthansa Technik itself has extensive APU capability on the main Honeywell and Hamilton Sundstrand units. LHT also has a 40% stake in Alitalia Maintenance Systems, which overhauls a range of APUs at its Rome Fiumicino base. The company has two test cells, one of them equipped to test units with electronic controls such as the GTCP331-200.

Alitalia's involvement in APU overhaul dates from the formation in the 1970s of the Atlas maintenance consortium that also involved Lufthansa, Air France, Iberia and Sabena. Atlas was formed to handle the new 747 and DC-10 widebodies, and Alitalia took responsibility for APU overhaul and repair on those types plus the A300. Maintenance Systems was established in 2003. Nowadays its old Atlas partner Iberia Maintenance overhauls both the GTCP36-300 and the 131-9A for the A320, plus the MD-80's GTCP85-98DHF. Annual throughput in recent years has been about 30 units. Elsewhere in Europe, Finnair Technical Services overhauls, repairs and tests the APS3200 and TSCP700-4B/-E, while JAT Tehnika in Belgrade is the sole source in eastern Europe for GTCP85 series APU overhaul.



Turkish Technic established its APU shop in 1972, carrying out minor repairs initially for the GTCP85-98CK used by the 727, the DC-9's GTCP85-98D and the DC-10's TCSP-700. After building its own test cell in 1981, Turkish Technic started to overhaul and test the units. Current capabilities cover Honeywell and Hamilton Sundstrand units for the 737 Classic, the 737 NG's GTCP131-9B and the A320's APS3200, plus Honeywell's A310, MD-88 and 727 APUs.

In Dublin, parts of the former SR Technics/Aer Lingus facility have been bought by start-up Dublin Aerospace. SRT had invested more than EUR3 million (\$4.5 million) in the APU shop a couple of years before it closed down its operation there, and Dublin Aerospace has announced plans to restart APU overhaul alongside narrowbody maintenance and landing gear overhaul. The APU activity will focus on the Honeywell GTCP 85, 131-9B/A, 331-200/250 and 331-350 series.

The Americas

The United States is home to the two principal manufacturers of APUs, some of the world's biggest airline shops and an array of independents. Hamilton Sundstrand Power Systems (HSPS) alone has a 23,000-sq ft repair facility in San Diego, opened in 2002, that has the capacity to overhaul more than 800 APUs each year. In 2008, to increase flexibility for customers, HSPS appointed StandardAero the first authorised repair facility for the E-170/-190 family's APS 2300 APU.

Airline shops naturally tend to focus on the equipment associated with the parent carrier's fleet. American Airlines

Maintenance Services (AA-MRO) has the repair, overhaul and test capabilities for the 737NG's 131-9B and had immediate induction slots available in January. AA-MRO also offers short-term leasing of all model GTCP85-98DHF APUs for the MD-80.

Delta TechOps also overhauls the 131-9B, plus the MD-90's 131-9D, the 331-200 for the 757/767 and the 331-250 for the A300. United Services supports the 331-200ER for the 757/767 plus the 777's 331-500B and the 747-400's PW901. United has a contract with Honeywell for piece part repairs on the first two, while piece part repairs for the 901A go to Pratt & Whitney Canada. In January the company's test cells were in the process of being correlated to the OEM specifications. Shop throughput at San Francisco in 2009 amounted to 72 331-200s, 27 331-500s, and 15 901As.

TAP Maintenance and Engineering Brazil has the most comprehensive APU shops in South America, with capability covering Honeywell and Sundstrand units for all Boeing models except the 777, most Airbus and Embraer types, the DC-10 and MD-11.

Back in the USA, there are several independent shops, including Aircraft Power & Service in Durant, Oklahoma, Chase Aerospace in Orlando, Piedmont Aviation Component Services in North Carolina, Triumph Air Repair in Phoenix and United Turbine Technologies (UTTI) in Miami.

As the world's biggest independent APU shop, Triumph maintains most of the Honeywell range, as well as the PW901. Because it carries out repairs at its own or other Triumph Group facilities, it claims near complete control over parts rework schedules and offers

Lufthansa Technik is one major provider of APU repair and overhaul. It has the capability to perform maintenance on seven major types.

cost per flight hour, fixed price and not-to-exceed support agreements as alternatives to time and material contracts.

UTTI also stresses its parts restoration capability, saying its vendors restore parts that others would return as beyond repairable limits. It also has a substantial stock of rotatable and new parts that enables it to offer a consistent 25 day turn time. UTTI specialises in GTCP85 series units for the 727 and 737, the DC-9 and the MD-80, plus the 36-100/-150 used by regional and corporate operators. Chase, which handles a wider range, including GTCP331s for the 757/767 and A300/A310, also maintains an inventory of serviced APUs and replacement parts to help protect turn times.

Asia Pacific

In the Asia Pacific region the APU support pattern is a familiar one of long-established airline shops supplemented by local OEM shops and joint ventures between OEMs and local operators.

All Nippon Airways, Japan Airlines, Korean Air, Qantas and PIA all have APU overhaul capability. Garuda's former maintenance centre, GMF AeroAsia, overhauls a range of Honeywell units. In Taiwan, Air Asia maintains capability on the GTCP85-98 and -129 series APUs used by the 727, 737 Classic, MD-82, DC-8 and DC-9.

In addition to its APU overhaul base in Singapore, Honeywell has a joint venture in China with TAECO Aerospace. Established at Xiamen in 1995, Honeywell TAECO Aerospace (Xiamen) has Chinese, Hong Kong and FAA certification and overhauls the GTCP85 and GTCP331 for airlines in China and regional carriers in north Asia that operate routes to China.

In India, Honeywell has picked Air Works to become the country's first Honeywell authorised service centre. Air Works maintains ATR 42/72s and 737 Classics and NGs at Hosur, near Bangalore: the agreement with Honeywell covers avionics and the TFE731 and CFE738 engines for business and general aviation aircraft as well as APUs. **AC**

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