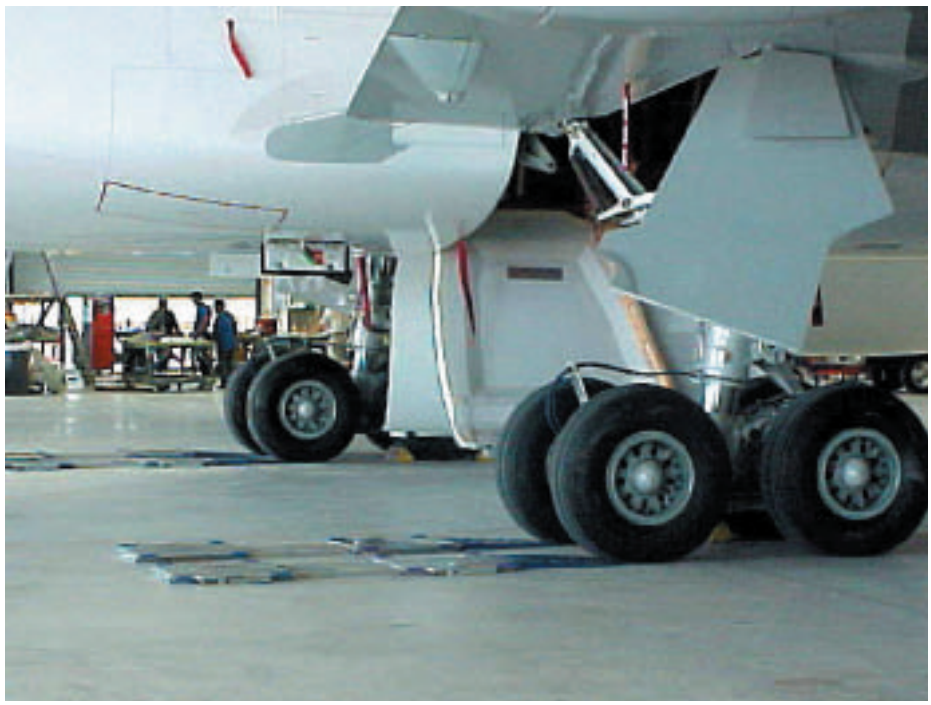
Aircraft weighing on a large scale ...

There are two principle methods to weighing an aircraft: the 'platform scale' method — which is fast becoming the de-facto standard — and the 'load cell' technique. Each approach has its advantages and disadvantages depending on the specific application in hand. *Aircraft Technology* looks at both the technology evolution and operation of aircraft weighing equipment.



Platform scales from General Electrodynamics Corporation (GEC). More expensive to purchase, but much simpler to use than conventional top-of-jack load cells.

All aircraft gain weight over time. In large aircraft especially, there are so many 'nooks' and 'crannies' where dirt, dust and moisture will be retained within the airframe. In addition, over the course of a number of years service, repairs, repainting, interiors outfitting, as well as major structural modifications generally impose significant weight change. These are good reasons why aircraft weighing is an essential process which all aircraft should undergo at least every three or four years. Changes in airframe weight are of particular importance since the operating empty weight will be directly affected, which in turn determines the allowable weight of payload, fuel and passengers (based on an average weight per passenger) which may be carried without exceeding the certified maximum take off weight.

The other factor is the need to ascertain any changes in the location of the centre-of-gravity (CG) otherwise known as the 'balance point.' By knowing this accurately, the cargo or passenger operator knows exactly where to 'load the load'. Crucially, if the CG changes too much, without the airline being aware of it, then operational safety could be compromised.

It is also worth mentioning that another less talked-about application for aircraft weighing is during the flight testing of new aircraft being developed by the aircraft OEMs such as Airbus and Boeing. In extreme cases, prototype aircraft will be loaded-up with fuel and weight ballast right up to or even exceeding the in-service maximum take-off weights.

Weighing methods

There are two principle methods to weighing an aircraft. The 'platform' method, which is fast becoming the de-facto standard, involves the operator pushing or towing the aircraft onto a large scale pad at ground level — much like a large bathroom scale. With one scale per wheel, each device should be capable of measuring up to at least 60,000lb, since the weight on each wheel will rarely exceed this figure (heavier aircraft just tend to have more wheels). The A380 is a good example, since the this ultra-large airliner will have no fewer than 22 wheels to spread the huge load on the ground, such that the maximum pressure imposed on the ground by each wheel will not exceed that, of say, a present-day B747. But what this does mean, is that at least 22 individual platform scales will be needed!

The other weighing method is to jack the aircraft off the ground while supporting the aircraft on a set of load cells between the top of the jack, and a hard point on the aircraft. The load cell is typically a small round device about the size of a baseball which comprises a hardpoint load-bearing cup, as well as an analogue-to-digital PCB underneath it. In general the jack/load cell equipment is cheaper than the platform type, especially as many operators already own the appropriate jacks for their particular aircraft, so they do not have to make that investment.

However, there is no escaping the fact that jacking the aircraft off the ground from all load points

simultaneously introduces logistical inconvenience as well as safety risks which some operators would rather avoid by opting for more expensive, but simpler-to-use platform equipment. In addition, the weighing process from start to finish with platform scales typically takes only one third of the time compared with using load cells.

In the case of both the platform and jacking methods, the measurements are conveyed either via a cable leading out to an indicator where the readings are taken, or they can be transmitted via a radio-frequency (RF) signal out to a remotely located indicator, and most recently, using non-electromagnetic infra-red transmission.

"Our most recent technology," explains Harold Thomas at **General Electrodynamics Corporation** (GEC), Arlington, TX, "is the transmission of the weight information via RF transmitter out to a small digital readout module. We use our own proprietary software which instantaneously calculates the C of G on receipt of the respective weights via RF transmission. Originally the information was displayed on the scale itself and one had to apply a latitude correction factor, or an accuracy correction factor. However, with the newer technology we have now improved the accuracy of the scales. Today we manufacture scales which are 0.1 per cent accurate. So from 0 to 60,000lb, our scales read in one pound or kilogram increments and plus or minus one per cent of applied load, such that at 60,000lb, for example, we would have only a maximum of 60lb potential error."

"With shear-beam load cells, one cannot really measure the side loading. It is only really accurate with true vertical loads. The newer self-levelling pressure transducer device enables accurate readings in off-level conditions."
— Harold Thomas, General Electrodynamics Corporation

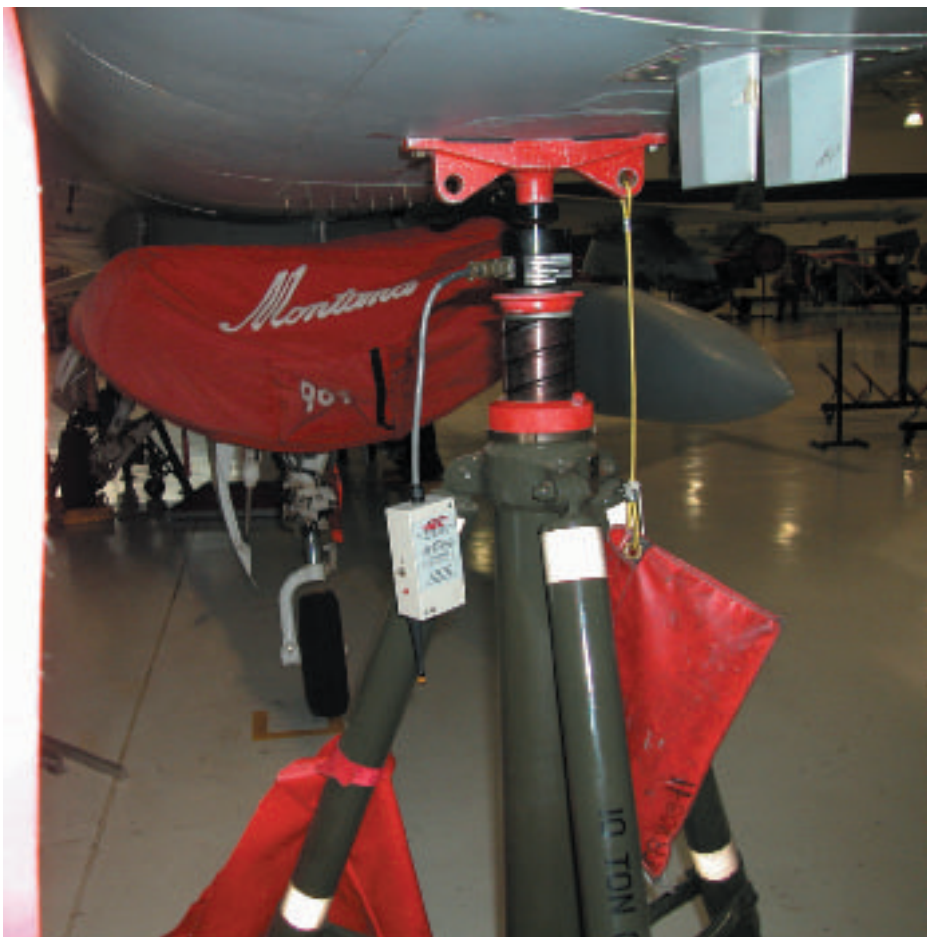
Meanwhile, supplier **Intercomp Aircraft Weighing,** based in Minneapolis, reckons its AC30-60 platform scale is the industry's "most technologically advanced wireless weighing system". The technology will weigh virtually "any aircraft" due to the full range accuracy of ±0.1 per cent of applied load or better. The device will provide the accuracy necessary to obtain reliable readings for all types of aircraft. Importantly, the AC30-60 features eliminate the need for manual corrections thereby providing a more accurate and faster weighing process. A B747 can easily be weighed in under one hour, including the system 'set-up' and 'take-down', which translates into the ability to maximise payload and reduce man hours. Intercomp manufactures both digital output load cell kits and fully electronic platform scales for airlines, manufacturers, maintenance centres and defence agencies. Customers include Delta, American, Northwest, Korean and China Airlines, Boeing, McDonnell Douglas, ITPN, Cessna, IAI, Lockheed Martin, USAF, US Army, Bell, Westland, Agusta and Sikorsky Helicopters, TAECO, SASCO, and others. It is also the prime supplier to NASA for the weight and balance of all Space Shuttle Orbiters.

Another notable supplier is **Revere Transducers** — now part of **SI Technologies**. This company's main offering is the JetWeigh system which incorporates the latest digital technology combined with software enhancements and stainless steel hermetically sealed load cells. Enhanced software has replaced many manual functions and adjustments, reducing the possibility of human error when calculating centre of gravity or recording data including. The digital computer has the latest integrated flash memory technology for storing measurements and a built-in library of over 200 different aircraft types, as well as back-up protection to prevent loss of data in the event of a power failure. The company also produces a range of 60,000lb capacity platform type scales which meet the 0.1 per cent of applied load accuracy. Its calibration and service centre is located in Tustin, CA.

Shear-beam load-cell vs self-levelling pressure transducer

With regard to the load cells themselves, there are two approaches: the traditional "shear-beam load-cell" (SBLC) and the newer "self-levelling pressure transducer" (SLPD) which uses precision pressure transducers with piezo-resistive semiconductor sensors. The top piston of a self-leveling load cell automatically orients itself to be perpendicular to whatever force is applied to it. It can do this at an angle up to five degrees off the perpendicular angle. It also has a very low profile, which delivers a number of advantages including a high rating for fatigue life.

"With the SBLC one cannot really measure any side loading," explains Thomas. "It is only really accurate with true vertical loads. The newer approach of a self-levelling device coupled with a pressure transducer enables the operator to achieve much more accurate readings in 'off-level' conditions, and do so with greater reliability. Moreover, the SBLC device utilises a piece of metal which deflects with weight and the extent of the deflection should be proportional to the weight. However, over time, that metal fatigues and stresses and it does not return to its original state which therefore introduces inaccuracies and unreliability. For this reason, most manufacturers provide no rating or guarantee on the life cycle of a standard shear beam load cell. In contrast, the pressure transducers used in the self-levelling load cells have a rated life cycle that is greater than one-million cycles. This gives the user a huge margin of confidence



Wireless load cell, top of jack configuration. GEC Scales.

that the load cell will perform accurately longer requiring less frequent calibrations. It is also worth noting that our older-generation platform scales can be up to four inches high, and weigh up to 140lbs each, whereas our new equipment is less than two inches high and weighs roughly 70lbs per platform."

One might naturally ask why not just install weighing devices directly into the landing gear struts?

Thomas points out that while there are indeed a few in-built systems today — called 'on-board weight and balance' equipment — they are not accurate enough to be considered a primary system to replace an external scale because they do not meet the 0.1 per cent of load input weighing accuracy. "There are various anomalies and conditions which affect the on-board type of equipment used to gather the readings, with the levelling being one of these. And presently there is nothing available today which allows you to do that accurately enough. Having said that, I can reveal that this company does have three patents for an improved on-board weight and balance system. Indeed, we have undertaken some R&D work in this area, and in the near future we will demonstrate our prototype and subsequently hope to introduce a device which is actually built into the landing gear of the aircraft."

Calibration

In a similar way that aircraft weight is "calibrated" using scales throughout its operational life, the scales must of course also be periodically calibrated. To this end each scale manufacturer specifies a method for checking the linearity / calibration curve, usually through proprietary software. "We use a correction 'curve' with a minimum of 10 linear points throughout the full range of the scale. However, if fewer points are used, especially if they do not coincide with the weight range being used, then the chances are such a scale will not be not accurate to 0.1 per cent."

In addition to the manufacturer's own conformance certification, there should also be full traceability right back to the US National Institute of Standards & Technology, which effectively proves the accuracy of the standards used to calibrate the scales. Moreover, each customer can either have its own calibration and maintenance capability for the equipment on-site, or the equipment can be sent back to its original supplier for the calibration certification. This should take place at least once each year, although sometimes this is accomplished every 90 days. It should be noted that as the scales age, their calibration cycle shortens and so scales will gradually require re-calibration on a semi-annual or even a quarterly basis.

"We will run a plot of the accuracy of the scale once we receive it, and then we will know whether the scale is within tolerance at the time. If it is not, we run a new calibration

procedure and plot the new data for the guaranteed 0.1 per cent accuracy, and both the 'before and after' information goes back to the customer," adds Thomas.

FAA Advisory Circular 120-27 revision

While there is no hard-and-fast regulatory enforcement of weight techniques and equipment compliance, there is nevertheless an FAA advisory circular (no. AC 120-27C) dealing specifically with weighing operations and frequency of weighing for commercial operators, which is presently being revised by the Aviation Rulemaking Committee (ARC). This is being revised to include more stringent standards, and in the case where there were no standards, specifying the type of equipment to be used along with the need to display values in one pound increments. For example, some equipment presently in use displays weight in 10lb increments.

According to the FAA's aircraft maintenance division, the goal is to adjust the average weights used by all operators which have an approved weight and balance control programme which was predicated on the average weights contained in advisory circular 120-27C, *"Aircraft Weight and Balance Control"*. In January 2003, a regional commuter aircraft experienced a fatal accident on departure. This accident raised concerns related to aircraft loading and average weights used in weight and balance control programmes. The 'adjustment' is to be used until such time as AC 120-27C can be validated and/or revised.

Regarding the use of a standard 'average' passenger weight, which has hitherto been around 170lb, it should be noted that in the US, the average weight is certainly *not* 170lb. People are getting larger than they were when that standard was established, and flight crew especially would like to use something closer to real weights. Consequently those numbers are being re-assessed. Even on a regional aircraft with 50 seats, the net difference between 50 times 170lb and 50 times 200lb is quite considerable. So while it is a small number per passenger, it adds up to a significant weight discrepancy with a full cabin load.

Thomas reckons that in terms of sales volume, the turnover of weighing equipment is fairly constant. "In all, the size of the weight and balance equipment market is probably around $10 million per annum. Of course this would comprise a wide range of products. For example you could have a customer who would use a load cell kit (i.e. the jacking method) costing $15,000 to weigh a B747, whereas for a platform system that figure might rise to around $75,000. It is therefore difficult to know what the full market potential is without knowing what kind of equipment operators are deploying. My guess is that there are probably around 150-250 weighing systems bought world wide (of all types), ranging from an inexpensive analogue load cell kit (less than $3,000) to a large platform system selling for $250,000."

Contract weighing services

Planeweighs, Swansea, UK, has been providing an aviation contract weighing service for around 25 years. It provides a European focal point for the servicing, calibration and rectification of GEC with European operators. Interestingly, the company is involved in incorporating new electrical technology into the product line which GEC make. It is also looking to manufacture its own scales at some point in the future. Regarding the infusion of new technology, it has decided to go down the route of infra-red data transmission due to the preference of the UK military which regard it as 'non-invasive' in contrast to radio transmission.

"We have a large contract with the UK military, notes Planeweighs' David Dickinson. "We support them with their weighing devices. Indeed, they have bought over 100 GEC weight and balance systems through us, which we maintain and upgrade. In all, we weigh between 500 and

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—David Dickinson, Planeweighs

600 aircraft per year. Moreover, of this number, about 40 per cent of our business is for commercial operators of aircraft ranging from the Saab 340 up to B777s and B747s. We probably conduct contract weighing regularly for most of the big names airlines in the UK, Ireland and also on the continent. In particular, we perform a lot of work in Ireland and we have equipment permanently positioned in Dublin because of the volume of work there. As a contract weighing company we have six million pounds of capacity in terms of the quantity of equipment we hold. For example, we can deploy enough equipment on any one day to weigh three B747s in any part of the UK. Notably, ninety per cent of jobs use roll-on/roll-off platform weighing, but we still retain the equipment for using the jack-head method of weighing."

The company is also active in retrofitting new technology into older equipment. For example, it has recently provided evaluation scales to Lufthansa which is considering modifying its weighing equipment to bring its 12 year old scales up to the latest electrical software standards.

"Scales which were produced 10-15 years ago are effectively obsolete in terms of electrical components, and are becoming increasingly difficult to maintain, especially as the chips will have disappeared from the market," notes Dickinson.

Looking ahead and to be ready for future, Planeweighs has already designed its latest scale to be capable of taking a fully-laden A380. "In less than couple of years time Airbus will be conducting flight trials at enormous loads and we will have a scale capable of weighing this aircraft. This will build upon the experience we have gained on Airbus development work for earlier types."