MARCHETTI-057_ Pt.3

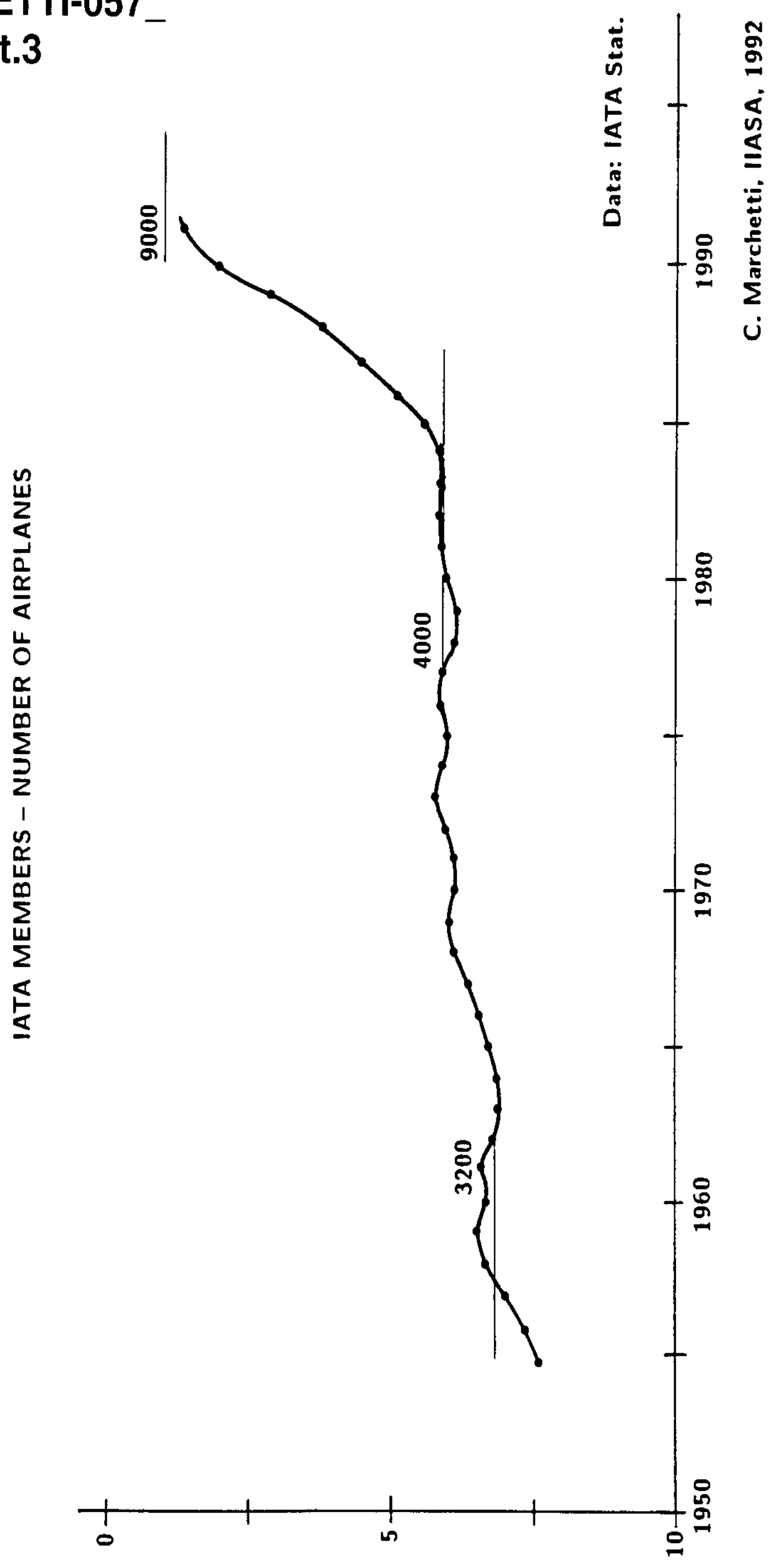


Fig4-6

The situation can be put in a sharper form by analyzing logistically the pulses of growth. The number of jets owned by IATA members show, e.g., two pulses of growth, one centered in 1965 and representing basically a substitution process eliminating piston planes. The second is a growth in the fleet. It is centered in 1988, exactly as the second pulse in pass-km growth of Fig.4-1. It is, however, much faster (6 y vs 12 y). This rush to buy brought airplane makers to overinvest in facilities (and air transporters may also have overinvested). The continuation of the recession period, which we forecast with ups and downs for the whole of this decade, may reduce the number of rich business travelers.

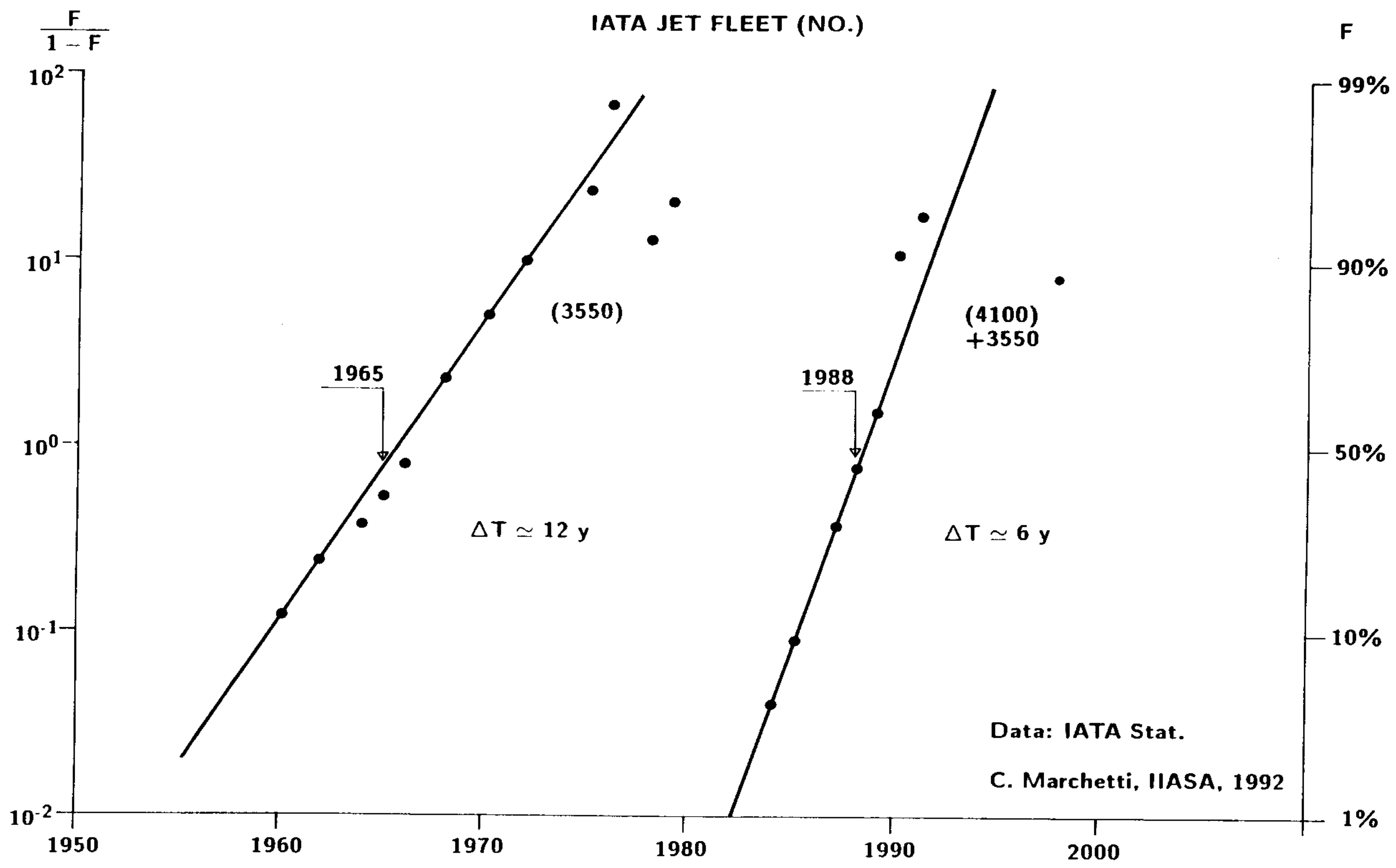
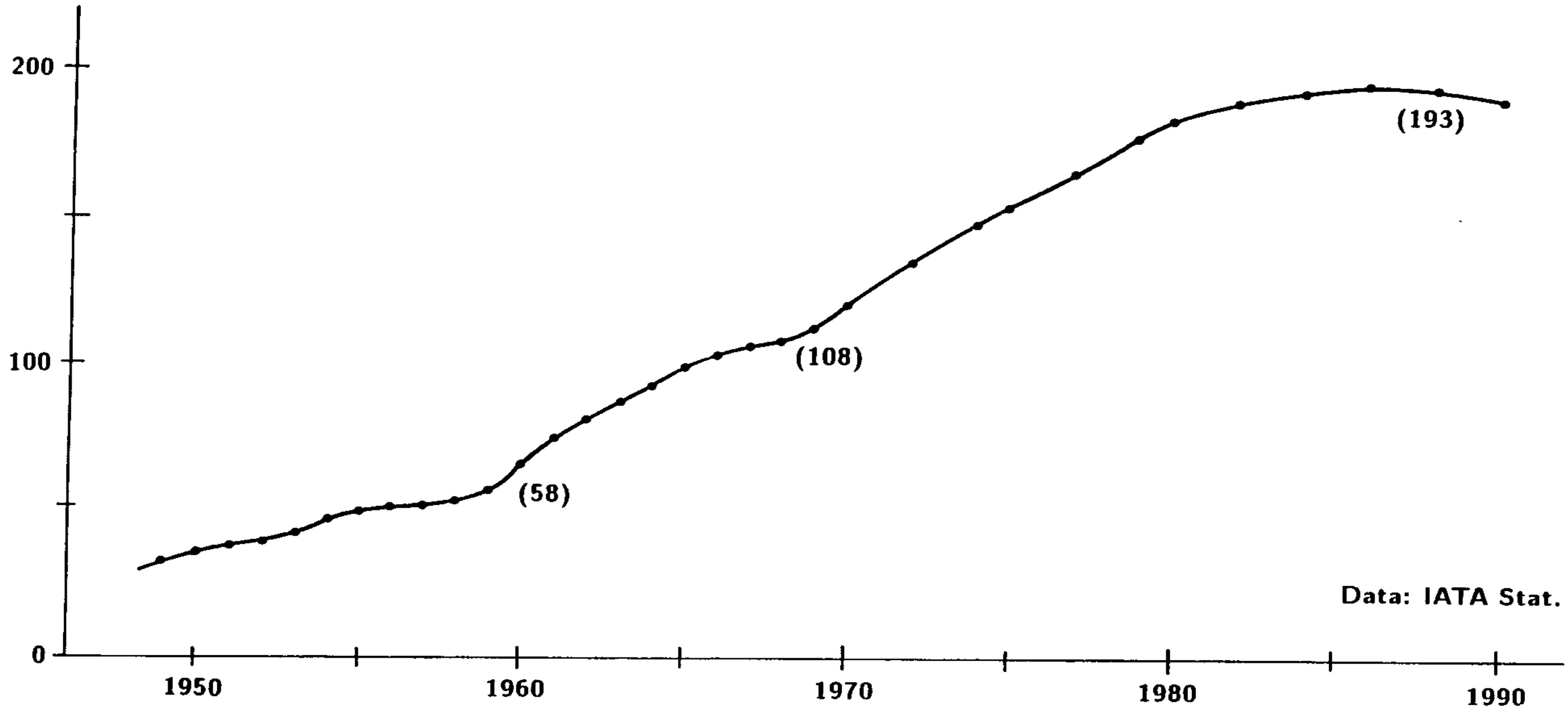

IATA JET FLEET (NO.)
F / 1 − F
F
10^2
10^1
10^0
10^{-1}
10^{-2}
99%
90%
50%
10%
1%
1950
1960
1970
1980
1990
2000
1965
1988
(3550)
(4100)
+3550
ΔT ≃ 12 y
ΔT ≃ 6 y
Data: IATA Stat.
C. Marchetti, IIASA, 1992

Fig.4-7

The long-term evolution of the size of the airplanes can be monitored through the mean seats per machine averaged over the entire fleet. This is a structural analysis only, as the larger machines have usually a much higher utilization factor. *Functionally* then the mean seats/airplane are higher. It is curious that also this growth comes in pulses we have analyzed logistically in Fig.4-4.

IATA – MEAN NO. OF SEATS/AIRPLANE

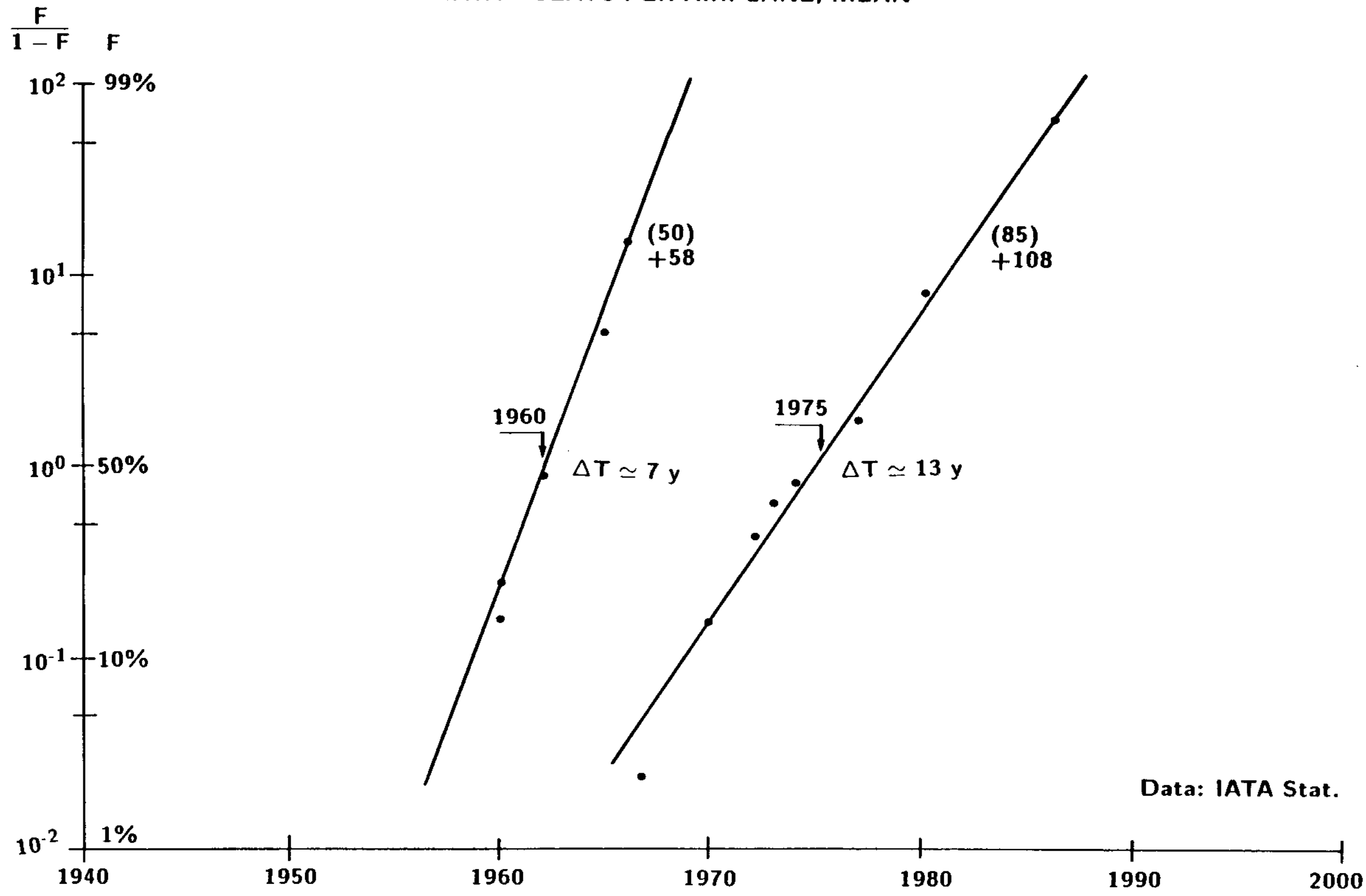


C. Marchetti, IIASA, 1992

Fig.4-8

The evolution of mean seats per plane can be crisply analyzed with logistics. We took the last two pulses of growth. The first one adds 50 seats to the 58 coming from previous history. The second pulse adds 108 seats to the previous 85. Growth occurs in fast pulses.

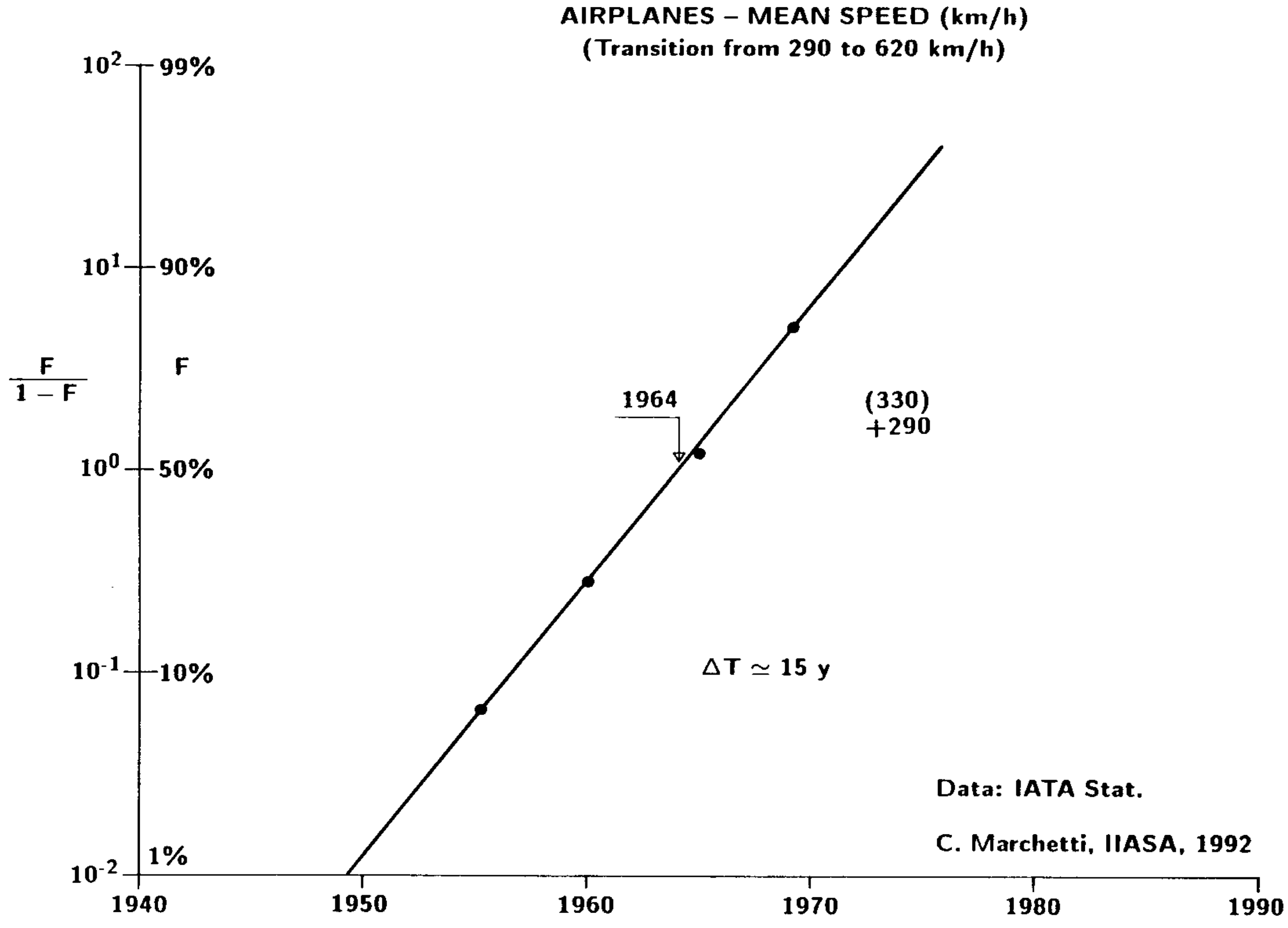
IATA – SEATS PER AIRPLANE, MEAN



C. Marchetti, IIASA, 1992

Fig.4-9

One of the factors in the productivity of airplanes is speed (productivity = speed × capacity). Monitoring speed gives an idea of the final effect of the introduction of jets. Speed moves from 290 to 620 km/h. This is weighted over traffic. Transport speed is measured from ground to ground and is substantially lower than cruise speed of the machines.



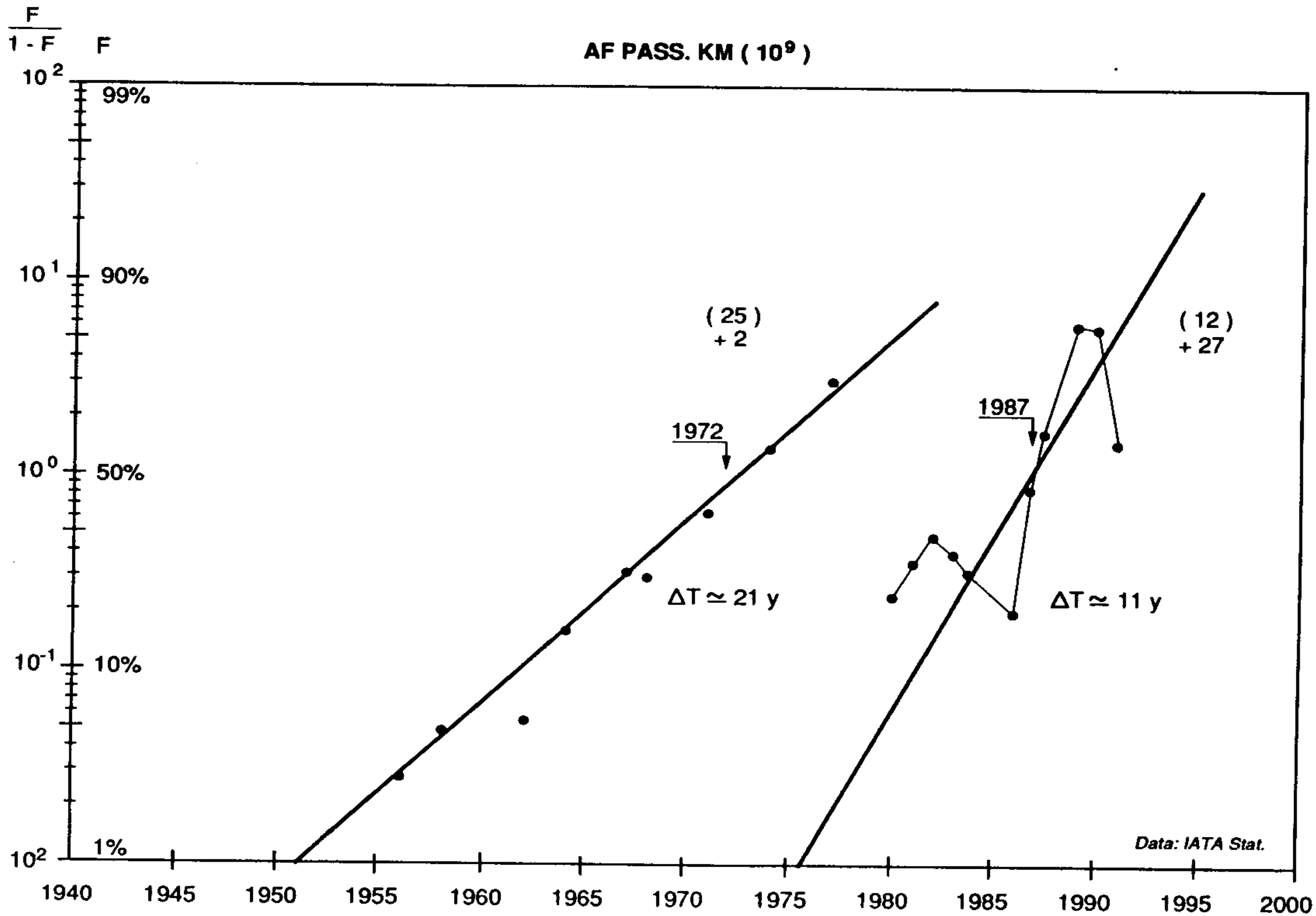
AIRPLANES – MEAN SPEED (km/h)
(Transition from 290 to 620 km/h)
$\frac{F}{1-F}$
F
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
99%
90%
50%
10%
1%
1964
(330)
+290
$\Delta T \simeq 15$ y
Data: IATA Stat.
C. Marchetti, IIASA, 1992
1940
1950
1960
1970
1980
1990

5. On Air Companies

The research being empirical in the first instance, we begin by modeling case histories. The situation at the moment is that *we have analyzed a dozen of air transport companies* (AA, AF, AZ, AUA, BA, FA, JAL, KLM, LH, Swiss Air, TWA, UAL) in terms of traffic, fleet, network, and employees. The first observation is that air companies reacted in very different ways to the surge of air travels in the eighties. Most had a corresponding second pulse of traffic. Some did not, like TWA. Some increased dramatically their network length like Lufthansa. Others did not, like British airways. Some increased their personnel with a second pulse, like Lufthansa, some kept it constant during the eighties in spite of the increase in traffic, like British Airways. We report all these taxonomic analyses in the hope of generating a background of information that may cast light on the reasons why some companies are successful and others are not. The formula we propose may appear relatively trivial, although much of the trouble air companies face come from not sticking to it. *First* the size of the planes must be adapted to traffic. *Second*, productivity of personnel must increase rapidly, meaning reducing drastically personnel in the next years of no growth, and *third*, fares must go down in Europe. With the very high present prices, elasticity will compensate the companies when lowering fares through a more than proportional increase in traffic. Extra capacity if already available. The companies on which we report in detail are Air France, Alitalia, British Airways, Lufthansa, and TWA, covering all types of behavior we have identified in a broader screening. The specific comments can be found in the legends.

Fig.5-1

Air passenger traffic for Air France was sticking to the rules until about 1980. The fitting logistic is centered around 1972, in good match with the center of the Kondratiev (1969) and the time constant of 21 years matches all the process inside the cycle (saturation of 1972 + 21 = 1993). Around 1980, however, a new (quite irregular) wave starts, centered in 1987, and saturating again around the end of the cycle. It adds about 55% to the saturation level of the first wave.

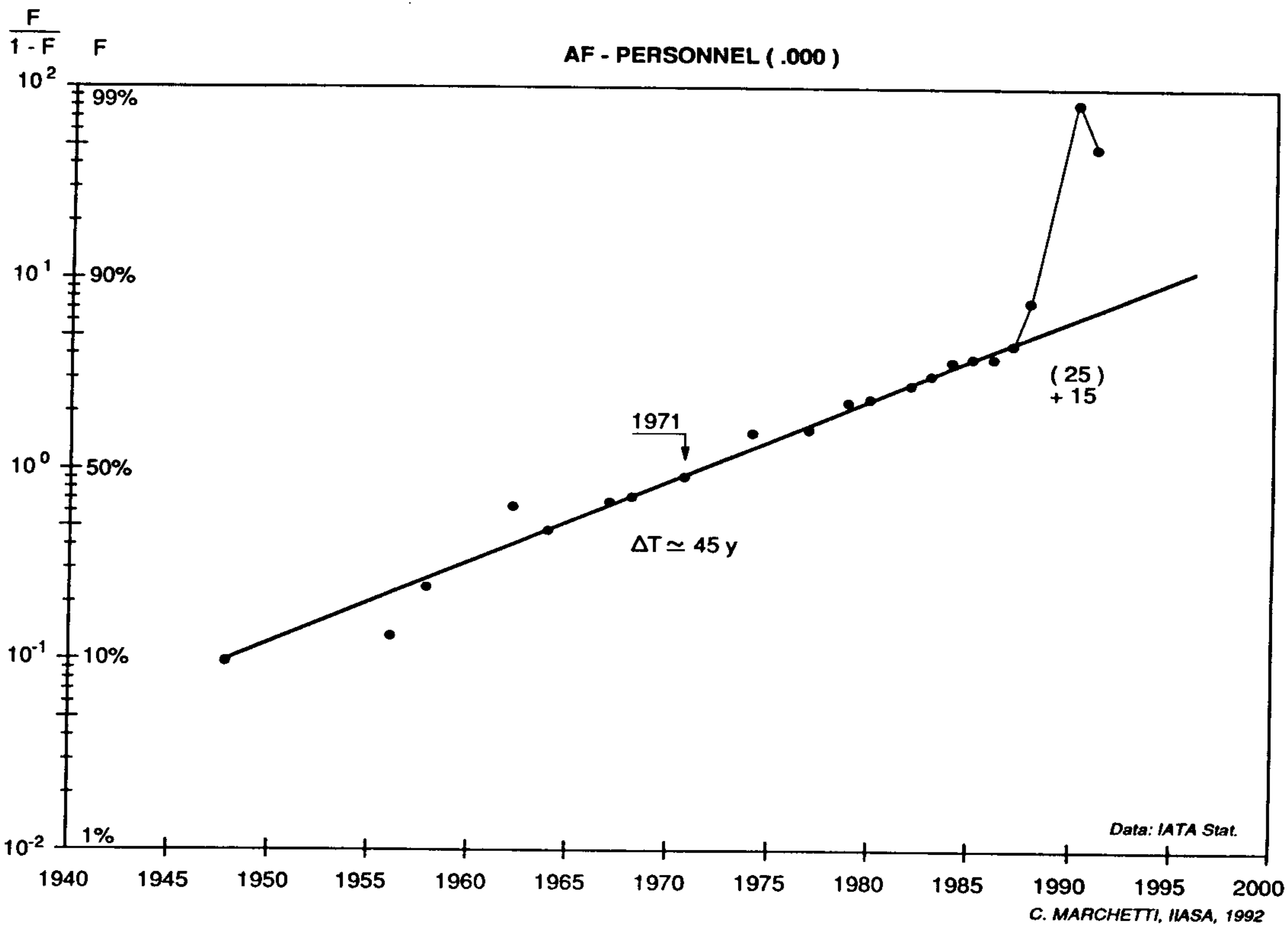


C. MARCHETTI, IIASA, 1992

MARCHCH3.DRW

Fig.5-2

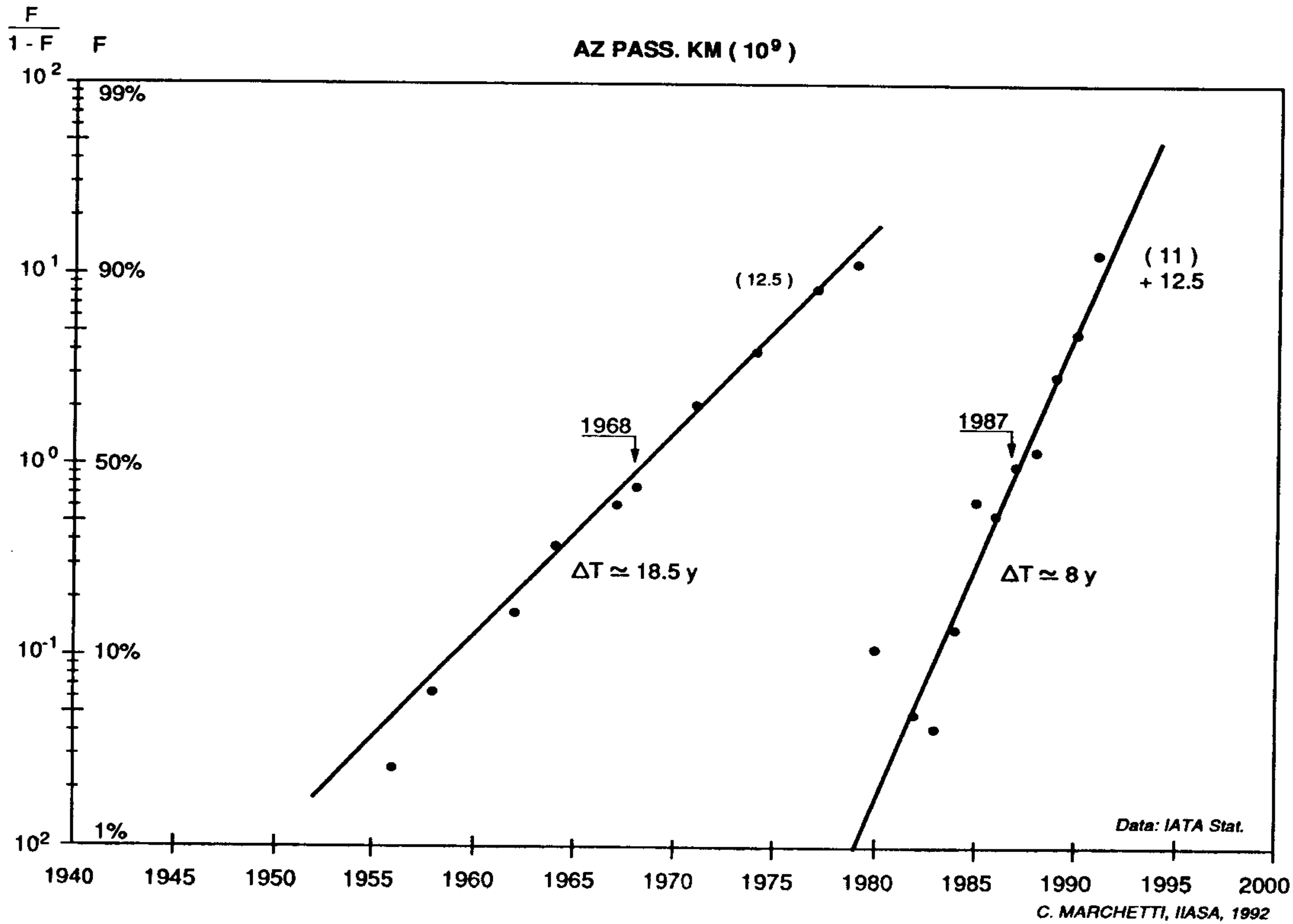
Airfrance personnel does not show a two-pulse situation. The glitch in 1988, although only anticipating the saturation, may be reabsorbed. The centerpoint is correct for fitting into a Kondratiev. The ΔT is suspiciously too large. Perhaps the analysis should be repeated with different parameters before trying to extract conclusions.



MARCHCH1.DRW

Fig.5-3

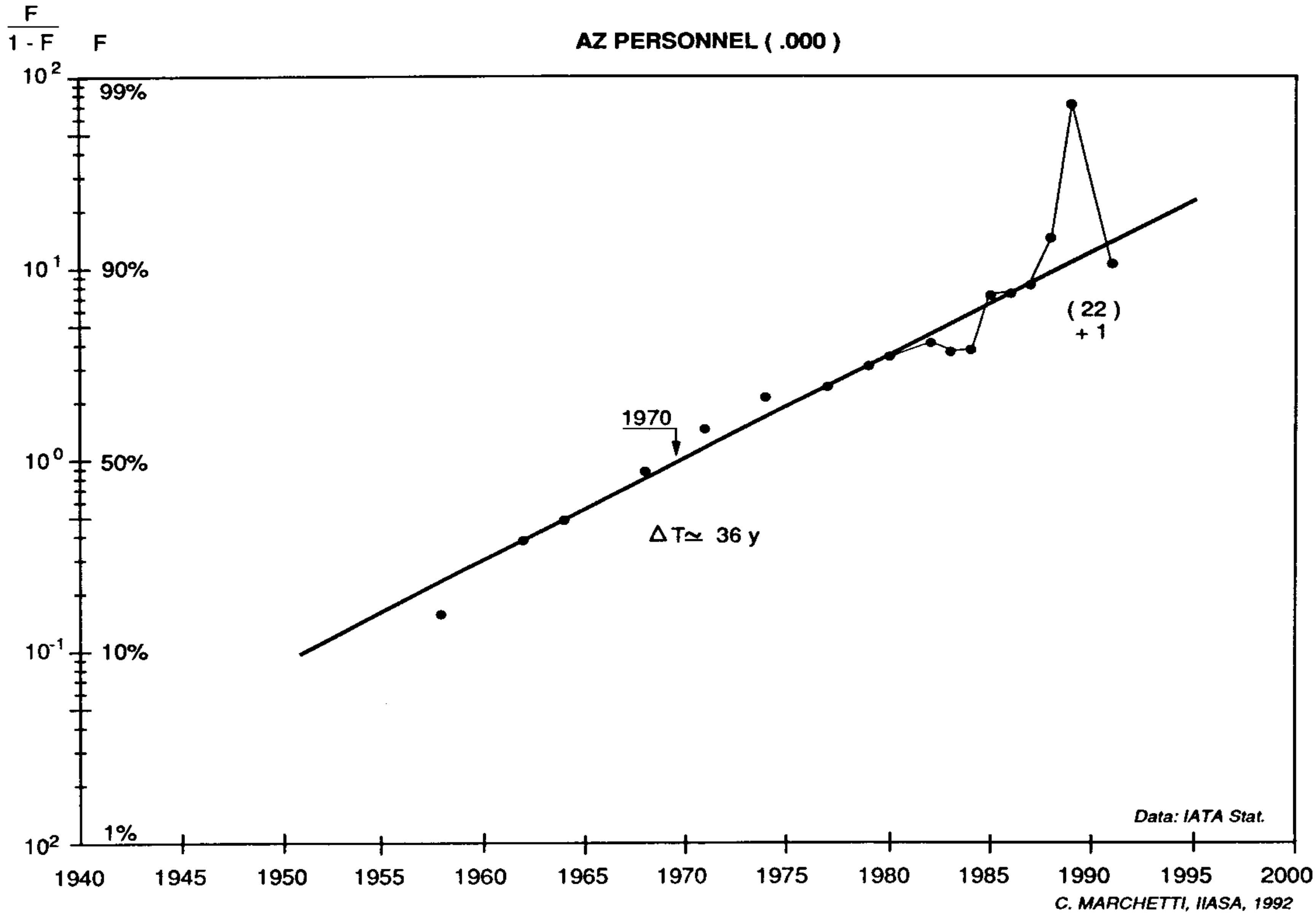
Alitalia has two well delineated pulses describing the evolution of its pass-km performed. The first one is co-centered with the Kondratiev cycle (1969) but with a somehow too short time constant (99% saturation in 1968 + 18.5 = 1986.5). The second pulse is centered in 1987, in tune with that of world transport (1988) but shorter (8 years vs. 12 years). Pass-km reporting to the first pulse are now saturated. The second pulse saturates (99%) in 1987 + 8 = 1995, so that the increase in pass-km for Alitalia should be marginal.



AZ PASS. KM (10⁹)
F / 1 - F
F
10 2
10 1
10 0
10-1
10²
99%
90%
50%
10%
1%
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
1968
1987
(12.5)
(11)
+ 12.5
ΔT ≃ 18.5 y
ΔT ≃ 8 y
Data: IATA Stat.
C. MARCHETTI, IIASA, 1992

Fig.5-4

The logistic for personnel growth for Alitalia is correctly centered in 1970 (Kondratiev 1969) but has too large a time constant (36 years) to fit snugly into the cycle (optimal $\Delta T \simeq 28$ years). Curious is the little flare in 1990, luckily reabsorbed. Because traffic is practically at saturation (Fig.5-3), Alitalia should start reducing personnel (3 to 4% per year).

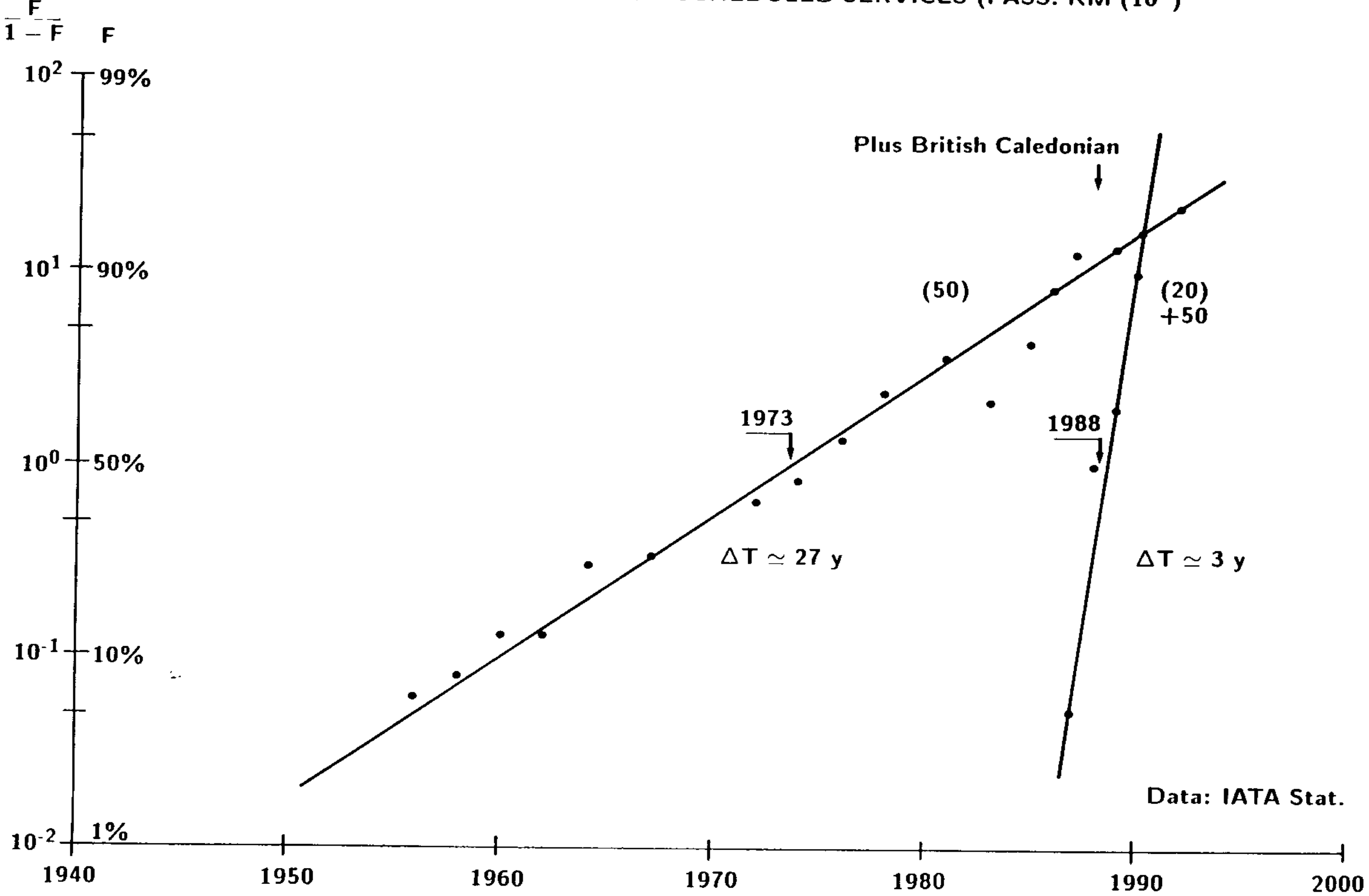


MARCHCH2.DRW

Fig.5-5

British Airways fits very well the Kondratiev cycle with a centerpoint of the growth logistic in 1973 and a ΔT of 27 years. The second spurt is extremely fast, with a ΔT of only 3 years, but centered in 1988, exactly as the world pulse of Fig.4-1. The short time constant means that in only 3 years 0.8×20 or $16\ 10^9$ pass-km extra, flowed through its network. Of these about half were carried in through the absorption of British Caledonian, so the real impact of the second pulse is very limited (about 15%).

BRITISH AIRWAYS – SCHEDULED SERVICES (PASS. KM (10^9)



C. Marchetti, IIASA, 1992

Fig.5-6

We report here the crude data about BA personnel without logistic analysis. The British Caledonian personnel seems to start being reabsorbed. The saturation in traffic (pass-km) suggests further reductions of personnel (3 to 4% per year).

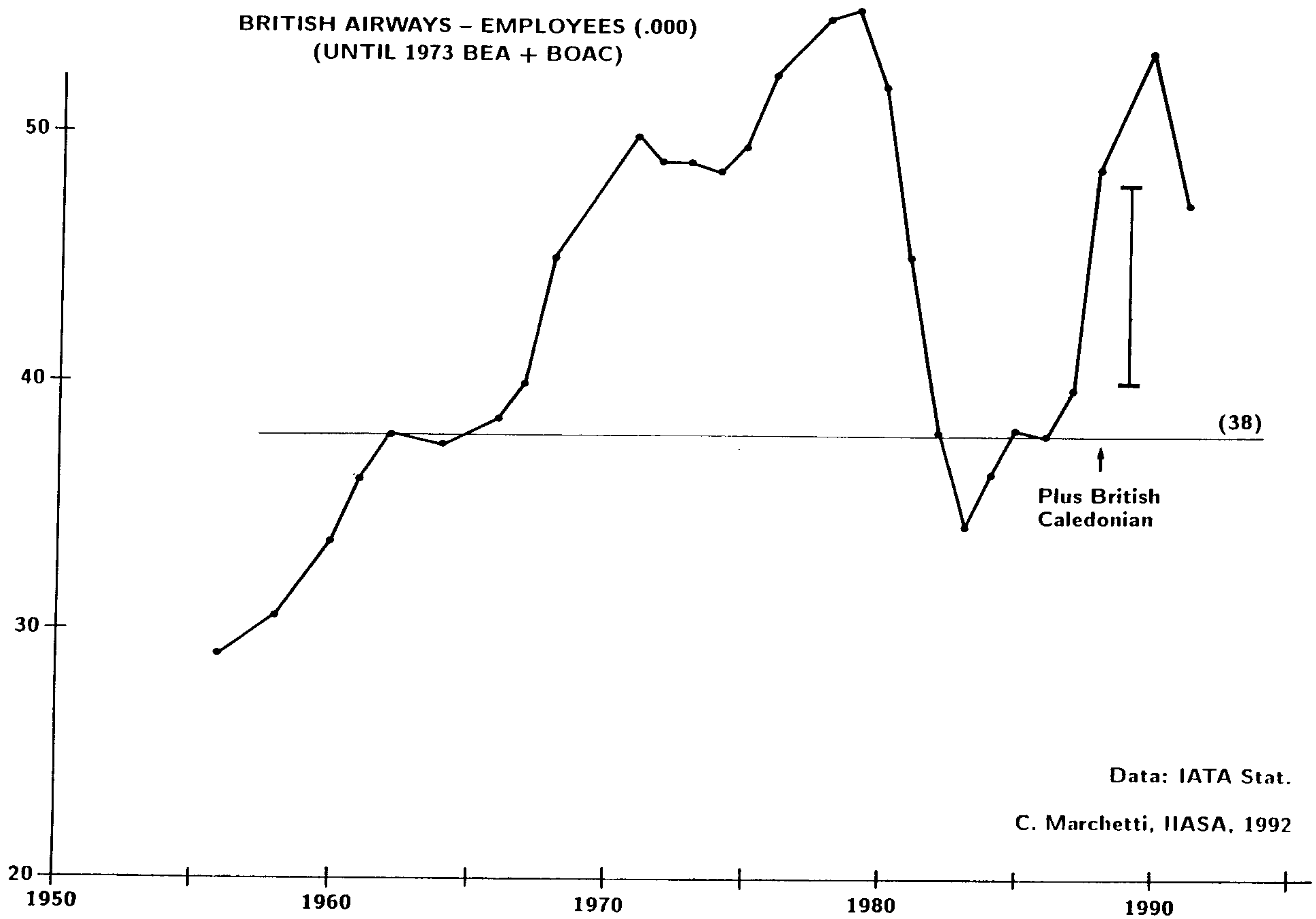

BRITISH AIRWAYS – EMPLOYEES (.000)
(UNTIL 1973 BEA + BOAC)
50
40
30
20
1950
1960
1970
1980
1990
(38)
Plus British
Caledonian
Data: IATA Stat.
C. Marchetti, IIASA, 1992

Fig.5-7

We can see here that the increase in traffic by BA has been obtained without expanding the network for more than 20 years.

BRITISH AIRWAYS – INTERNATIONAL NETWORK (.000 km)

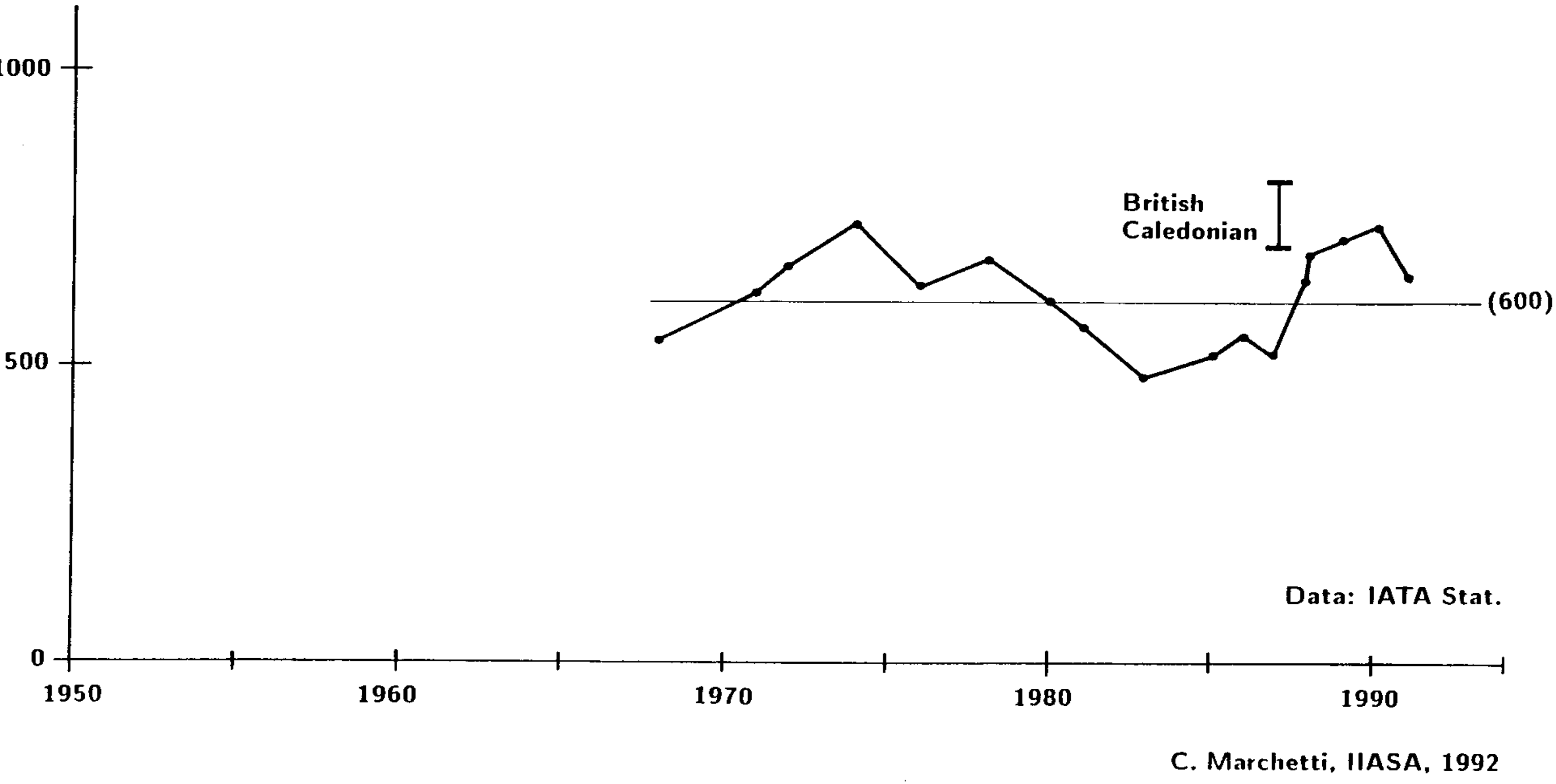


Fig.5-8

The example of BA shows how traffic can be expanded by a factor of 20 keeping the number of aircraft in service basically constant. Most of the increase in the last glitch is due to the absorption of British Caledonian, although the residual still shows some tension due, in our opinion, to the shortage of large planes on the market.


BRITISH AIRWAYS – FLEET NO. OF AIRPLANES
(UNTIL 1973 BEA + BOAC)
Plus British
Caledonian
(160)
200
100
0
1950
1960
1970
1980
1990
Data: IATA Stat.
C. Marchetti, IIASA, 1992

Fig.5-9

Lufthansa shows an extreme behavior in terms of profiting of the second pulse of traffic growth in the eighties. In fact, the second pulse, with 25 10^9 pass-km neatly doubles the level reached with the first pulse, of 25 10^9 pass-km. Looking at the timing $1974 + 22 = 1996$ and $1988 + 7 = 1995$, means Lufthansa is now out of steam, both pulses having almost reached saturation. The centerpoint of the second pulse (1988) neatly matches the centerpoint of the world traffic second pulse (1988), but the pulse is shorter.

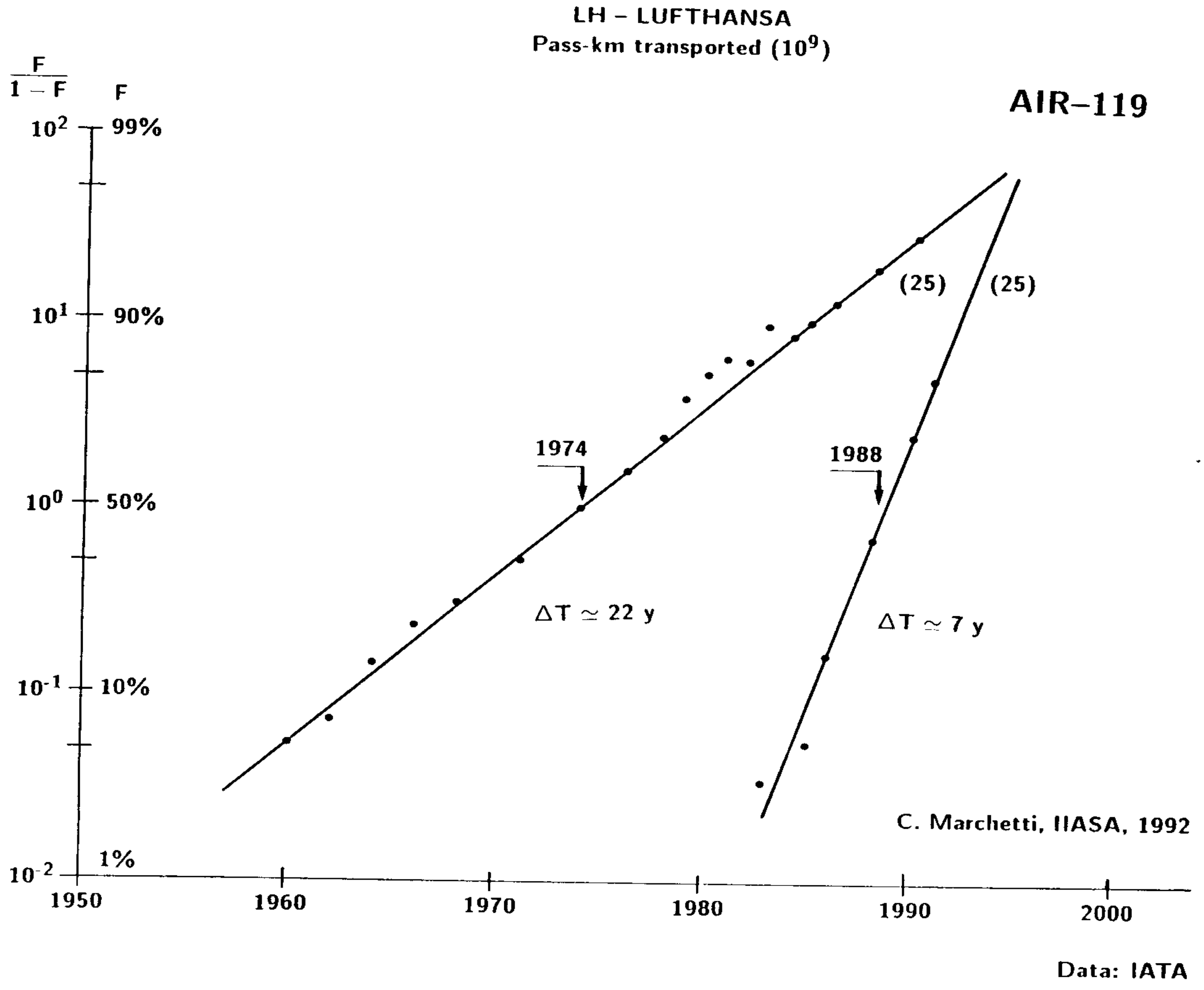

LH - LUFTHANSA
Pass-km transported (10^9)
AIR–119
$\frac{F}{1-F}$
F
10^2
99%
10^1
90%
10^0
50%
10^{-1}
10%
10^{-2}
1%
1950
1960
1970
1980
1990
2000
1974
1988
(25)
(25)
$\Delta T \simeq 22$ y
$\Delta T \simeq 7$ y
C. Marchetti, IIASA, 1992
Data: IATA

Fig.5-10

The first wave of personnel growth for Lufthansa follows perfectly orthodox lines with a centerpoint in 1965 and a time constant of 25 years. It saturates at 30.000 employees. The second wave centered in 1989 and with a time constant of 8 years matches the increase in traffic snugly, showing the company just expanded instead of profiting of the opportunity to do more with the same employees. The increase in employees is actually less than the increase in traffic. They increased only 70% when traffic doubled.

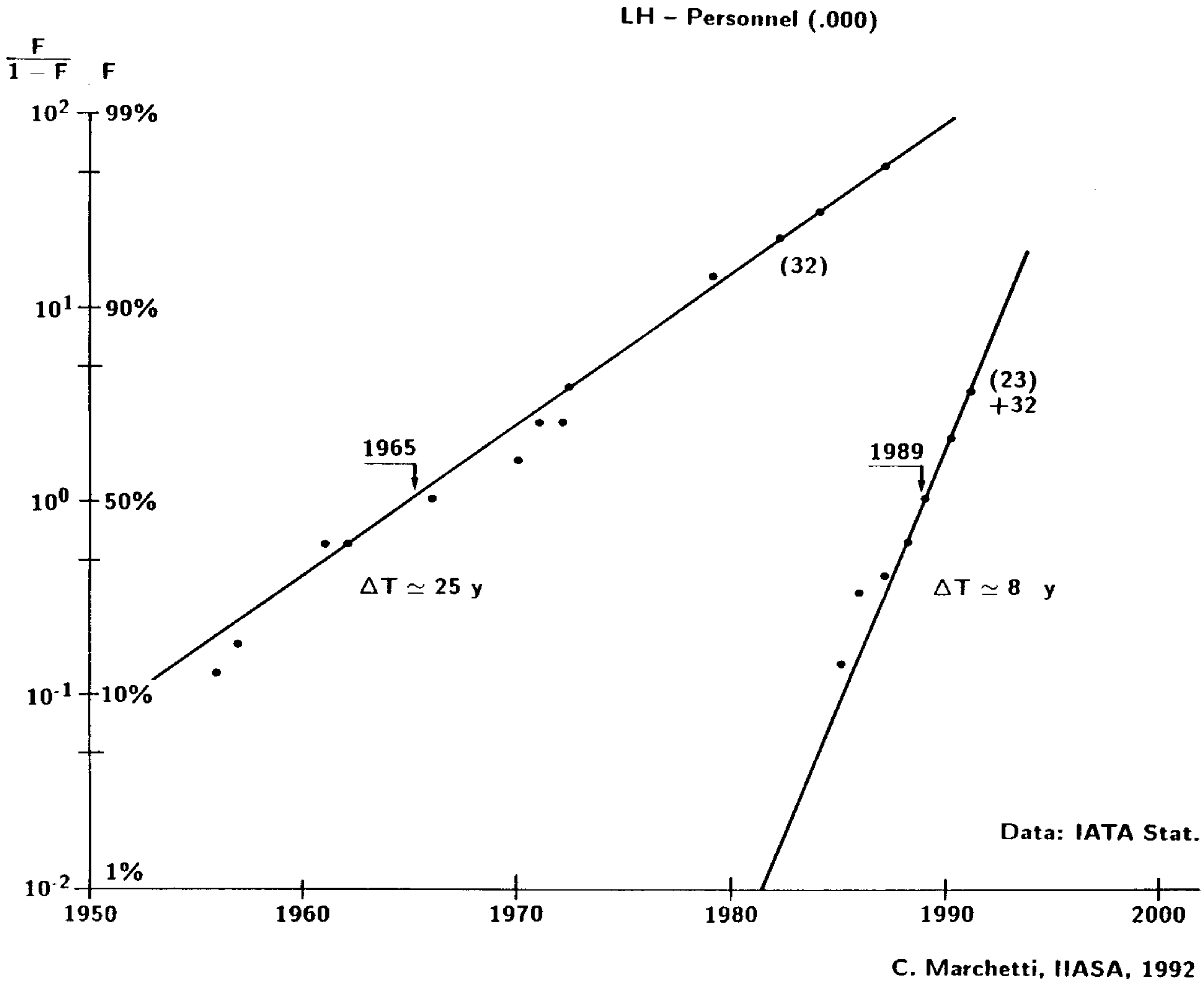
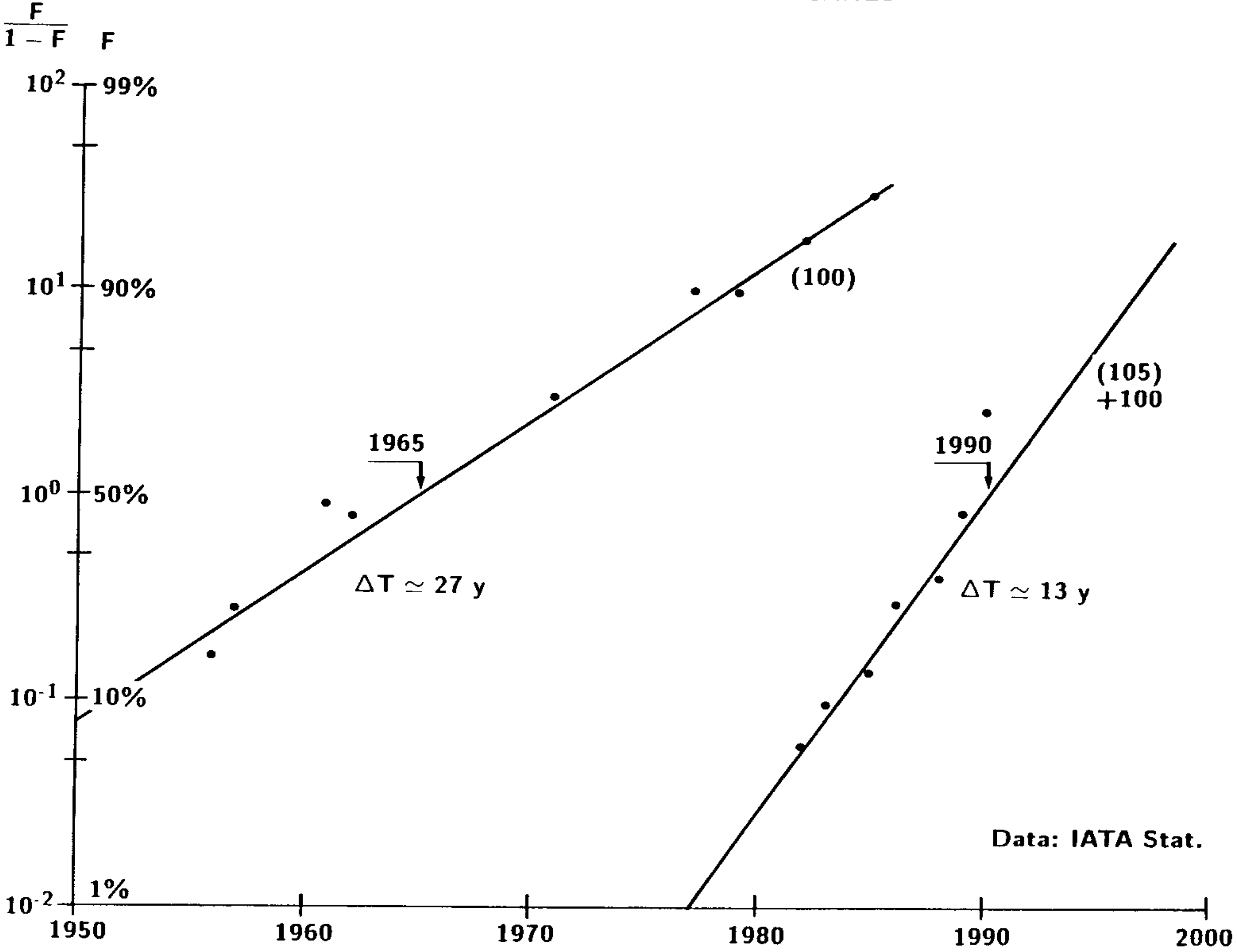

LH – Personnel (.000)
F/(1 – F)
F
10^2
99%
10^1
90%
10^0
50%
10^-1
10%
10^-2
1%
1950
1960
1970
1980
1990
2000
1965
ΔT ≃ 25 y
(32)
1989
(23)
+32
ΔT ≃ 8 y
Data: IATA Stat.
C. Marchetti, IIASA, 1992

Fig.5-11

Also the fleet size of Lufthansa follows the same script. In the first pulse it was moving toward one hundred planes to be reached at present time. But a second, fast pulse, centered in 1990, is doubling the fleet. The time constant of 13 years shows that the process should end in $1990 + 13 = 2003$. Because pass-km are saturating in $1988 + 7 = 1995$, there is a build-up of overcapacity.

LH – NO. OF AIRPLANES



C. Marchetti, IIASA, 1992

Fig.5-12

This chart gives perhaps the key to interpret what Lufthansa did. Its network length neatly doubles between 1983 and 1991 showing that its strategy was based on territorial expansion, with little intensification on the pre-existing network. Exactly the contrary of BA strategy. Incidentally LH at present has less pass-km than BA, but a network almost double in length. and a larger number of employees.

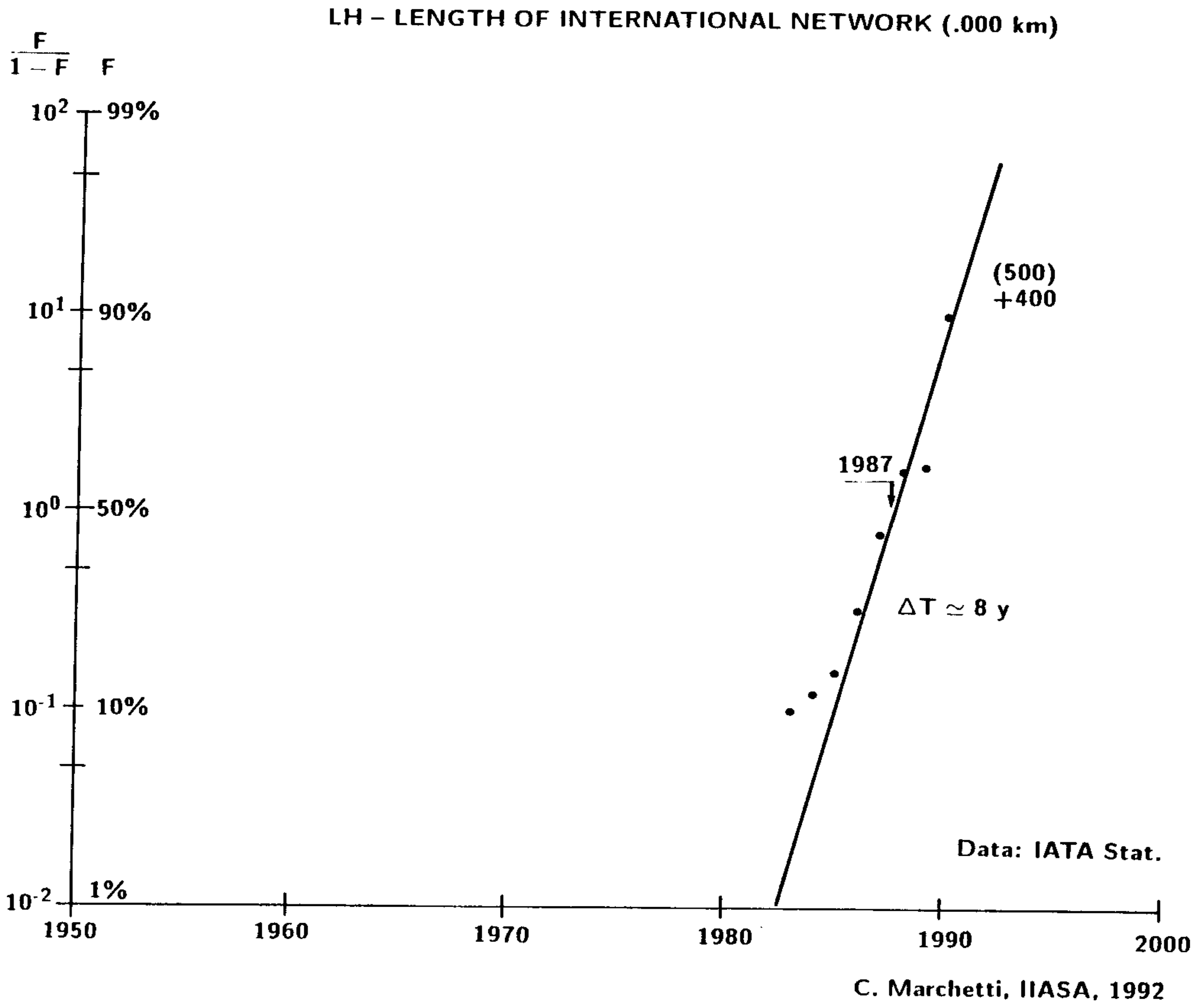
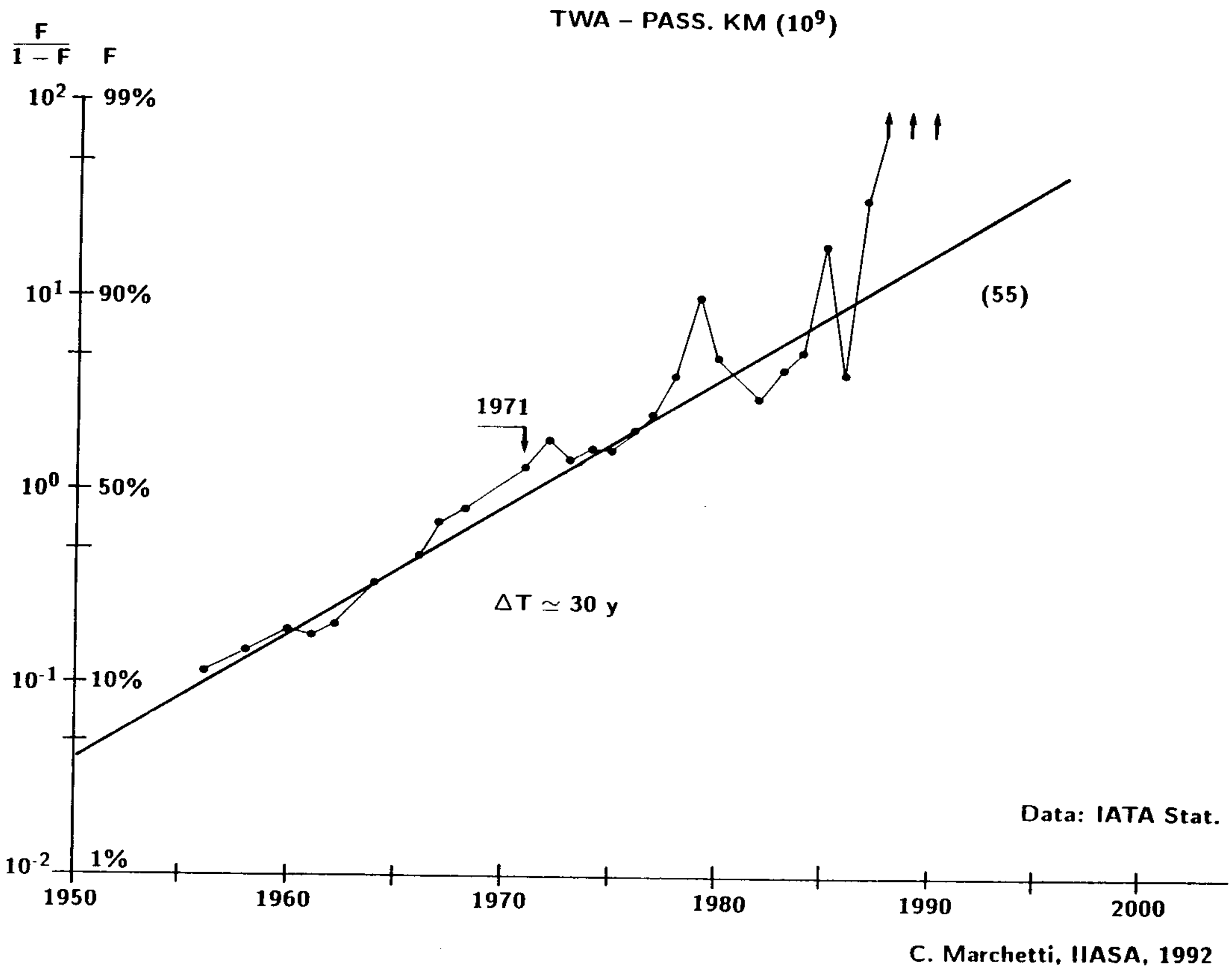

LH – LENGTH OF INTERNATIONAL NETWORK (.000 km)
$\frac{F}{1-F}$
F
10^2
99%
10^1
90%
10^0
50%
10^{-1}
10%
10^{-2}
1%
1950
1960
1970
1980
1990
2000
(500)
+400
1987
$\Delta T \simeq 8$ y
Data: IATA Stat.
C. Marchetti, IIASA, 1992

Fig.5-13

TWA is a glorious name in air transport, and much in trouble during the last decade. The numbers of TWA in our analysis might help detect the indicators of decay through taxonomic evidence. Looking at pass-km it is evident that TWA did not profit of the pulse of the eighties in world traffic. The arrows lead to figures inside the saturation point.

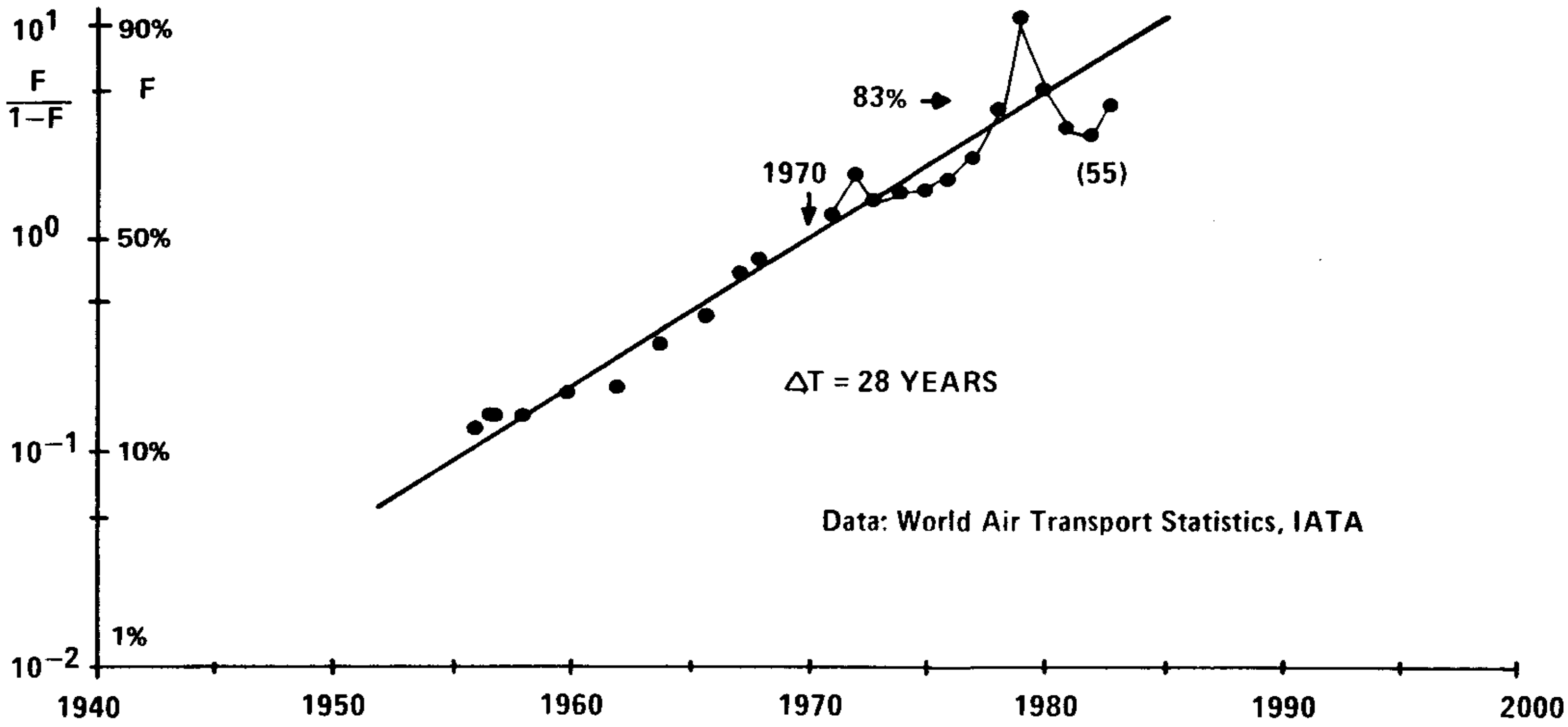


TWA – PASS. KM (10^9)
F/(1 – F)
F
10^2
99%
10^1
90%
10^0
50%
10^-1
10%
10^-2
1%
1950
1960
1970
1980
1990
2000
1971
ΔT ≃ 30 y
(55)
Data: IATA Stat.
C. Marchetti, IIASA, 1992

Fig.5-14

This is the same analysis as Fig.5-13, but done in 1985. The extra data (and improved fitting procedures) do not change much from the previous identification of parameters. 1983 could have been an excellent basis for forecasting.

TWA PASSENGER KM (10^9)



C. Marchetti, IIASA, 1985

Fig.5-15

The evolution of personnel in TWA has a course which seems uncorrelated with the evolution of TWA business. The sudden doubling around 1965 has no counterpart in the evolution of pass-km. Personnel was wisely reduced after reaching a maximum of 40.000 and is now 30.000.

TWA – EMPLOYEES (.000)

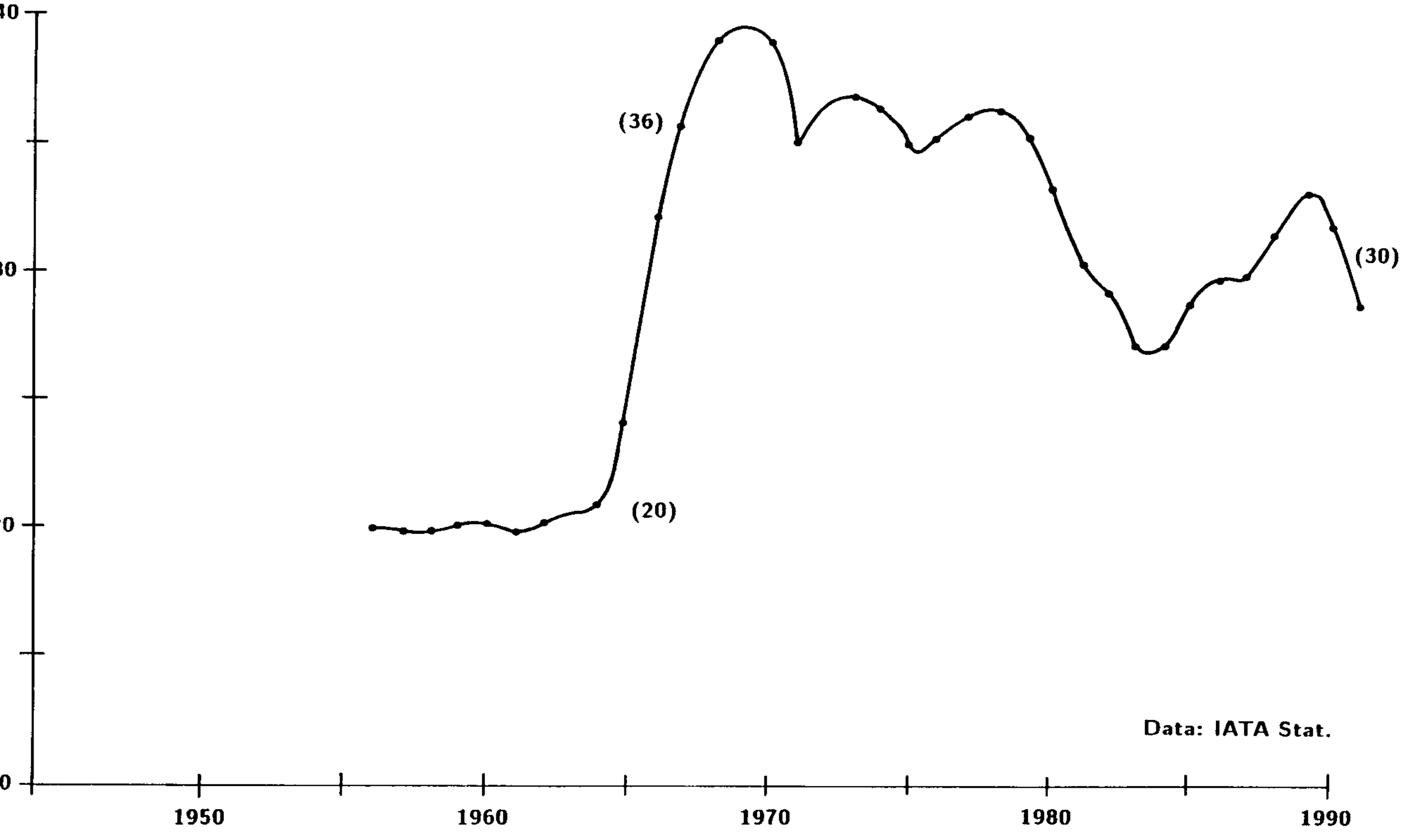


Fig.5-16

With ups and downs TWA fleet remained substantially constant. This is a positive sign meaning aircraft productivity growing in proportion to traffic as it should be.

TWA – NO. OF AIRPLANES

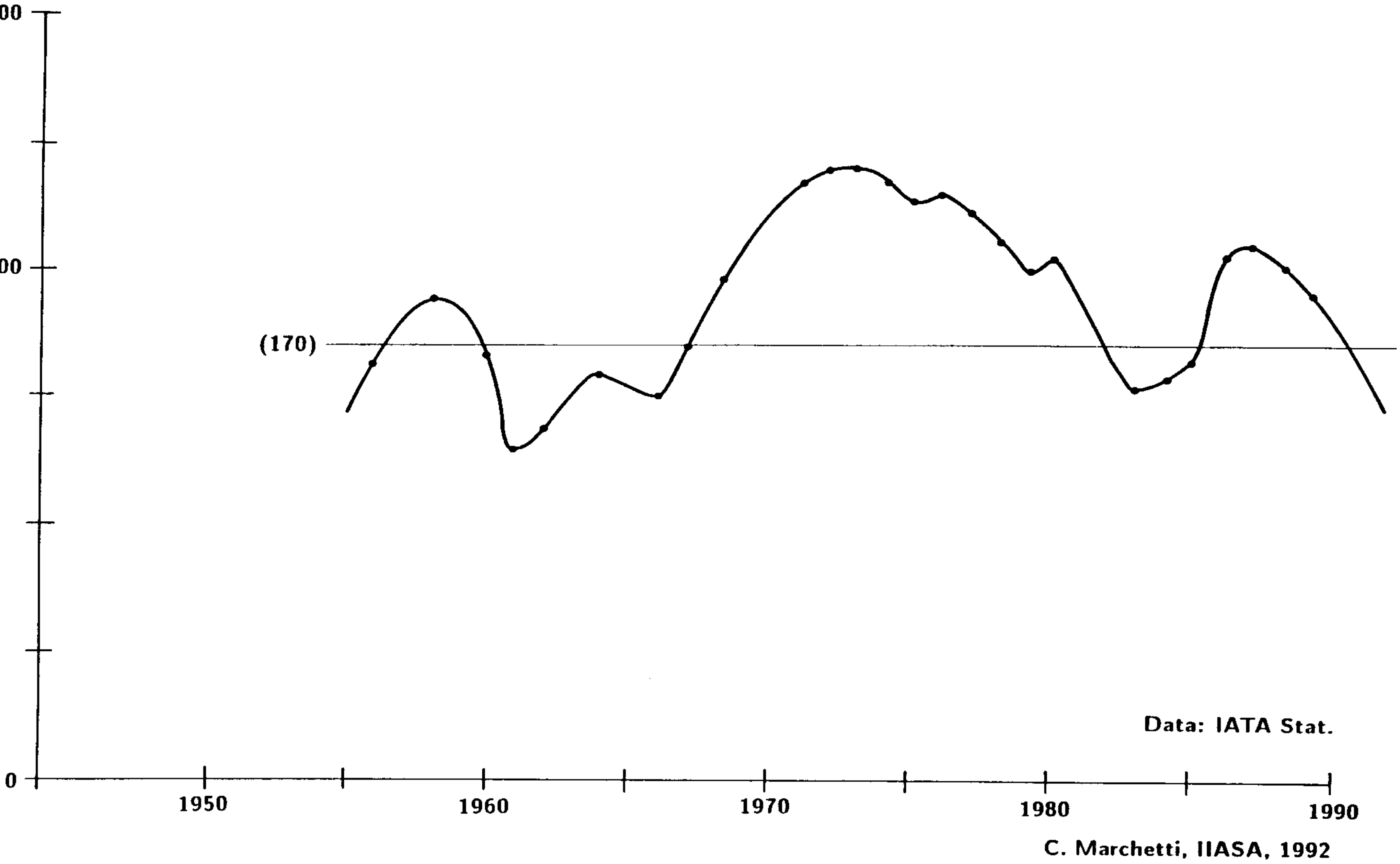
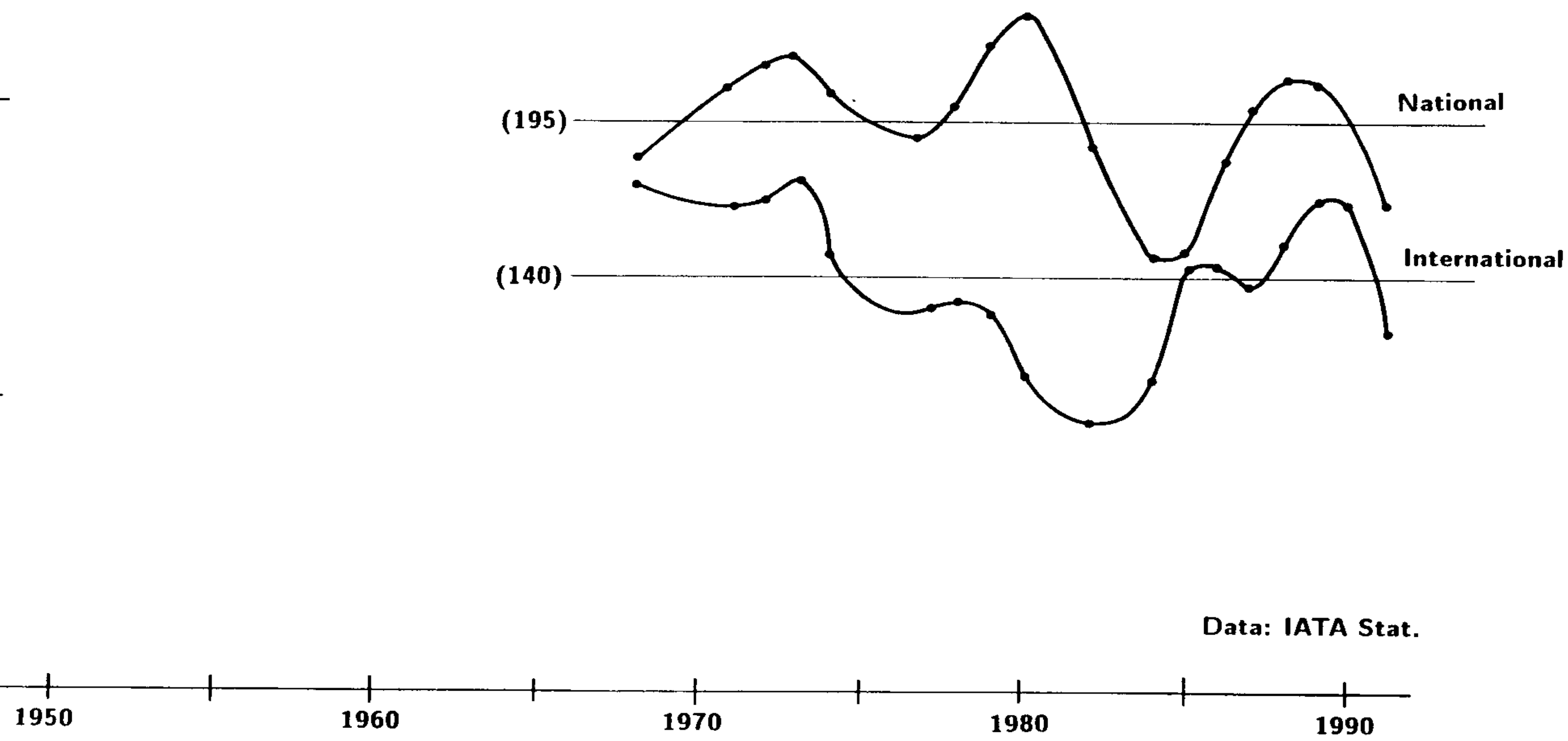


Fig.5-17

Also the network length, both national and international, remained basically stable during the last 25 years.

The interpretation of TWA troubles in the last years may be senescence and overstaffing.

TWA – NETWORK LENGTH (.000 km)



C. Marchetti, IIASA, 1992

6. On Airplanes

The most important parameter of an airplane from the functional point of view is its *productivity* which can be defined as the *product of capacity* (e.g., number of seats) *by speed.* It comes out as a flux: *pass-km/h.* Air travel *per se* can be defined as a flux if seen in the statistics as pass-km/year. One can divide that number by 10.000 and get the pass-km/h homogeneous with the units measuring the productivity of airplanes.

A historical analysis (Fig.6-1) shows that airplanes productivity always runs parallel to traffic flux. One of the interesting consequences is that from 1950 on, in spite of an increase in future traffic flux by a factor of about 40, the number of commercial planes stayed remarkably constant, around 4000. This rule has been broken during the last ten years or so, our opinion being that large planes were not available in sufficient numbers and very large ones not available at all.

The parallelism between productivity and traffic flux seems very rational as it *keeps vehicle congestion stable.* It can also be verified with oil tankers, whose number tends to be independent of the commercial oil flow over the oceans, and which again is around 4000. Accepting this point means that an increase in traffic by a factor of ten may require an increase in plane productivity again by a factor of ten.

This arithmetic will create problems. Planes operate at different hierarchical levels, basically four, although a fifth level is developing. Curiously the ratio in productivity between planes at successive levels upward is about 0.62 or the golden ratio. *It represents a fractal filling of a functional space.* For jets which have more or less the same speed, the number of seats can be 450–280–170–100. Anybody can recognize famous models carrying these numbers.

Multiplying by ten these figures makes no easy machine to engineer. Let us start from the first level now occupied by the 747. This first level is reported in Fig.6-1 where the makes are positioned by their productivity. With the increase in traffic airplanes became larger, and larger planes require more powerful engines. The development of engine capacity is reported in Fig.6-2. Piston engines are characterized by their HP, and jets by thrust (lb or kg force). Piston engines capacity grew logistically to a saturation point around 4000 HP. Their central problem was that of fluid flow. The complicated tubing and batch processing made air flow, i.e., power, limited. Jet engines operate with an unimpeded air flow, tendentially straight; they can gulp two orders of magnitude more air and reach one order of magnitude more power. Their problem is physical size. Apart from the sheer bulkiness, their power grows as the square of linear dimensions, but mechanical problems grow as the cube. The jet engine concept, as shown in Fig.6-2, appears to have deployed already most of its potential. However, one way is left open: that of moving air around engines faster. If we go, for example, to mach 7, the engine will gulp an order of magnitude more air than going at mach 0.85; the airplane also gets a productivity ten times larger for the same size. That way one can perhaps solve the problem of a $\times$ 10 productivity for the first level.

The second level should carry, say, $280 \times 10 = 2800$ people. Deplaning such slugs will create certain congestion at the bays, but let us look at the planes. Carrying 1000 people is no problem, and a beefed up 747–1000, already designed, could do it. This jumbo–1000 would carry passengers on three levels, like the old steamers. Fig.6-3 gives a humorous sketch of its problems. Multiplying such capacity by three with constant engine power means making the airplane plus fuel much lighter and the aerodynamics more sophisticated.

With new engineering and materials one can make air frames lighter and lighter following the historical trend. Aerodynamics and engine performance reduce the demand for fuel, and proportionally the fuel weight transported. Hypersonics are bound to use liquid hydrogen (LH_2) which is three times lighter than jet fuel. Its use may spill down in subsonic planes. Airbus industry is actually tinkering with an LH_2-fueled plane for medium range. A 3000-seat plane should lift 300 tons with passengers only. A 747 lifts now more than 100 tons of payload (and 100 tons of fuel) and a Tupolev 200 tons of payload. Our ambitious objective does not seem out of reach even if only patching up present technology.

Taking some cuts on numbers, a 747 at take-off may weight 400 tons, of which 100 tons are the paying load. The other 300 can be divided half–half between fuel and airframe. In our super-747 (operating at second level!) the paying load should be 300 tons, as said. The volume of the plane might be twice as large, but in the name of progress in engineering and materials, we keep the weight constant. Fuel consumption will decrease due to more efficiency in propulsion and in better aerodynamics. Even not including LH_2, and because a second level is relatively short range, we can make 50 tons for the fuel. Total weight would then come out to be around 500 tons. This means that runways can be the same as today for the second level down.

When new problems come, that even the best patch-up of old technol-