THE EXAMPLE OF LAPTOP BASED PERFORMANCE DATA GENERATING AND OPTIMIZATION IN CONTEMPORARY COMMERCIAL AIRCRAFT OPERATIONS

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Summary

Airframe and engine combination gives equal potential to every operator with such a hardware combination. Operator's way of utilization makes its use to the maximum or less. Data related to aircraft performance is one of the basic elements in daily aircraft operations and optimal utilization of airframe and engine combination in real life environment. New technological solutions and systems affected performance data calculation. Today's laptop computer technology has already boarded the flight deck together with pilots.
This paper is to present possible structure and proposed application of one of the system together with envisaged effects of its use in real life commercial aircraft operations. It will present the overview of the system with considerations taken into account when designing and developing it; it's potentials and advantages compared to paper based performance data calculation and optimization: and the most important how it is understood as a tool in very demanding, unpredictable airline operations of today

1. INTRODUCTION

This paper is intended to present structure and proposed application of one of the removable personal computers (LAPTOPS) based aircraft take off performance calculation system together with envisaged effects of its use in real life commercial aircraft operations.

Performance data calculation and optimization reflect through the whole airline operation. They are related to flight safety as the ultimate concern in airline’s operation. Data availability and easy recalculation make airline's operation more safeguarded to operation disruptions and ad hoc modifications due to elements of today's very demanding traffic environment. Finally, the quality of data reflects on airline's bottom line at the end of the year as the result of possible savings in different areas of operation.

New technological solutions and systems have affected aircraft performance calculation. Early aircraft operations' paper based performance data calculation was subsequently modified to computer based calculation and rather facilitated optimization. Today's laptop computer technology has already boarded flight deck together with pilots. Their compact size made their utilization in such a confined space very easy. Commercial Of the Shelf (COTS) equipment of today is so powerful in terms of computation speed and memory storage that calculation and recalculation time is just a fraction of time needed for a manual calculation.

In order to present it, authors have tested the system on real life data related to airline operating conditions and aircraft. This data was compared to already known data related to pilots performance while doing same tasks in commercial aircraft flying. Although conclusion made upon this can not be generalized, as they are valid only for tested hardware, software, airports, and aircraft types, they have served the purpose of demonstrating advantages of such a system to manual calculation so common in today’s aviation.

The paper is intended to present the overview of system with considerations taken into account when designing and developing it; it's potentials and advantages compared to paper based performance data calculation and optimization; and the most important - how it is understood as a tool in very demanding, unpredictable airline operations of today.

Here are some terms related to airline industry terminology, not commonly used, in order to follow the paper easily:

TAKE OFF PERFORMANCE Take off performance are aircraft weight and characteristic speeds that describe take off from particular runway at given meteorological conditions (temperature, atmospheric pressure, wind speed and direction) and aircraft conditions.

FLIGHT OPERATIONS a part of every airline responsible for daily flying together with operations short term and long term planning and feed back analyzing from available flight data.

PAYLOAD weight (passengers, baggage, cargo and post) that generates income based on paid passenger and cargo tariffs.

FLEXIBLE TAKE-OFF – take-off at lower than maximum thrust setting allowed when taking-off at lower gross aircraft weights. This take-off mode results in lower engine wear.

2. AIRLINE OPERATIONS ENVIRONMENT

2.1 In the Past

Commercial flying of today differs in hardware used from the time in early 50s when first jet transport aircraft entered service. [1] Although main visible differences to passengers are in the size and comfort of aircraft the most substantial changes are not so visible. Power plant technology together with pilot to aircraft interface has experienced tremendous changes. It would not be strange if some of the pilots from the early days sit in the cockpit of today staring at completely different environment.

Instrumentation and interface leap has happened with the 'new generation' Airbus and Boeing aircraft. The Airbus A320 family aircraft cockpit of 80s compared to the A300 cockpit early 70s demonstrates reduced workload and improved safety. [2] The same situation is comparing the Boeing B777 aircraft cockpit to any of it's aircraft prior to it.

2.2 At Present Stage

Although pilot environment has gone through improvements and changes in general there are still some very strong links to the previous "era". Most of those links are due to widespread use of paper documentation and "classical" tools for aircraft performance determination and calculating.

Nowadays, airlines either subcontract or calculate take off performance for their aircraft by themselves. This data is presented in the form of tables showing the combination of either temperatures and winds or aircraft weights and winds. Take off performance tables calculation is done by computers and dedicated aircraft manufacturers' software.

Each runway requires separate table and there are multiple tables for every runway depending on the number of other specific conditions that airline wants to cover (flap settings, air conditioning and anti ice settings, different malfunctions on aircraft systems). [4]

Having in mind all said it is obvious that there are large number of different tables a crew needs to perform initial preparation and final calculation of their take off performance for each flight. Crew selects particular table that corresponds to their take off situation (runway, meteorological conditions, aircraft condition). In case there are some deviations from standards set at the time of table production they also have to perform some calculations to apply prescribed corrections making their calculation valid for given take off conditions.

2.3 Projected in the Future

Contemporary LAPTOP computer technology has brought improved computational and memory storage power and their reduced size. All this has lead to the idea of their application in everyday calculation just prior to take off at particular airport. Main grounds for this decision were: short recalculation time in the case of change among conditions describing take off, and improved precision during calculation process and in final results.

There are two distinct steps proposed by Airbus Industrie for implementing this idea into the life. The first proposed step is implementing low cost commercially available computers for enhanced flight operations functions (take off performance calculation, weight and balance calculation). Hardware for this step comprises of LAPTOP powered by batteries that need recharge at aircraft power supply.

Next step would be aircraft server linked to avionics and two LAPTOPS. This hardware combination would be used for aircraft manuals update, enhanced flight operations functions, and maintenance data transfer through wireless gate-links at speed 100 times faster than today's Aircraft Communication and Reporting System (ACARS). [3]

Implementation of the first step is intended to ensure wider acceptance among airlines by using today's technology and limited aircraft cockpit modifications. Only after initial two phases it is envisaged incorporating the idea in the cockpit layout. This step is to be available sometimes after 2005 with the introduction of the Airbus A3XX airliner into commercial service. [4]

Airlines' support and help comprises of participating in the test program conducted by Airbus Industrie during the first step. It selected a number of airlines to conduct well defined and clearly planned program. Program has to asses: security, computational reliability, device reliability and robustness. [5] Three phases of testing are set to ensure that the final product will be close to airline needs.

3. SYSTEM'S STRUCTURE

The whole laptop based performance data generating and optimization system consists of two distinct modules. They are:

1. Raw data creation and system setting module,
2. LAPTOP based performance data calculation module.

Each of these modules requires particular hardware characteristics (in terms of Central Processor Unit (CPU) speed, and display resolution) that allow user to make system's performance exploited at their best.

Today's version of software is based on Windows 95 operating system. The issue of system stability hasn't been addressed during initial test phase. Decision whether it will be Windows 95 or Windows NT together with the possible use of Windows Server operating system, just because of convenient networking of laptops, are left for each airline's discretion.

3.1 Raw Data Creating and System Setting Module

This module is basically office based workstation. It requires at least Pentium CPU with clock speed of not less than 200 MHz. The main functions of this module are:

- ✈ setting airline's policy regarding: the use of units of measurement, regulatory set minimal requirements and conventions, together with standard operating procedures adopted by airline itself.
- ✈ defining airline's fleet for which program will be used: setting aircraft registry, and setting aircraft design maximum weights.
- ✈ setting runway characteristics for all airports, that airline is flying at, with specific fleet. Runway characteristics are defined in terms of specific runway lengths, airport elevation referred to mean sea level, and obstacles in take off direction (their distance and height). [2]

All data related to aircraft and engine characteristics are supplied by aircraft manufacturer. Presently, that is still done by CD-ROM. At the final stage in the future this will be done on line just to avoid obsolete data and make this process less time sensitive.[3]

3.2 LAPTOP Based Performance Data Calculation Module

The main visible element of the whole system to pilots is LAPTOP computer. It is still not decided whether it will be assigned to each pilot in command or just be a part of the documents and equipment required for each flight.

Minimum hardware characteristics for LAPTOP are Pentium CPU with system clock not less than 200 MHz and display of minimum 33 cm diagonal.

The system is used for performance calculation at the present stage of it's development. In next phases it is projected that other modules will be incorporated as well. That will make system more valuable in day-to-day operation. Aircraft weight and balance calculation interacting with take off performance data calculation is the first step. Modules that will adjust aircraft performance according to malfunctions present at a particular flight will be incorporated later on.

Raw data created in the office is transferred to LAPTOPs using some of the existing magnetic or optic media for data transfer. It is of very high importance to ensure full synchronization of data between originator of data and all LAPTOPs in use. Comparing one ore more floppy disks or even one CD-ROM to more than hundred paper pages (that are updated regularly for a just slight runway change) proves system's advantages over paper based performance calculation. The gain is in reduced workload and cost, together with improved efficiency and safety.

4. SYSTEM'S TASKS

LAPTOP based performance data calculations and optimization employs the same algorithms that are nowadays used for creating paper based tabulated performance data. There are two distinct algorithms that differ in precision and time required for calculation:

1. Polynomial,
2. 1st Principle,
3. Neural. [5]

While polynomial advantage is it's speed of calculation, 1st Principle generates more precise results. It has always been a trade between those two categories.

Polynomial algorithm is based on previously calculated graphs. Each of them is generated for specific values of input variables. No matter whether these are weight, wind speed, and temperature, all intermediate values are found using the basic set of graphs. The use of this procedure leads to the reduce calculation time. It is almost always 50% faster than 1st principle mode. Due to this advantage all figures are less precise – conservative [5].

1st Principle method on the other hand improves precision at the price of time required for calculation. Calculation is performed based on basic aerodynamic and aircraft engine thermodynamic equations. They are supplied through three distinct databases pertinent to each aircraft type and model. Each value is generated knowing aircraft condition data, meteorological conditions data, and other significant influential conditions (aircraft malfunctions and runway condition just to mention some of them).

A330243 - JAA | RR TRENT 772B engines | DUBAI | 12 | 15.0.2 25 JUL 99 AB243A01 *V13

QNH 1013.25 HPA
Air cond. Off
Anti-icing Off
All reversers inoperative

Elevation 34 FT TORA 3999 M
Isa temp 15 C TODA 4148 M
rwy slope 0.20% ASDA 4059 M

3 obstacles

DRY
TOGA

OAT	CONF 1+F					CONF 2				
C	TAILWIND -10 KT	TAILWIND -5 KT	WIND 0 KT	HEADWIND 10 KT	HEADWIND 20 KT	TAILWIND -10 KT	TAILWIND -5 KT	WIND 0 KT	HEADWIND 10 KT	HEADWIND 20 KT
0	248.1 4/6 150/63/69	253.4 4/6 156/67/72	257.9 3/6 163/72/77	260.0 6/7 167/76/81	260.0 3/7 164/76/81	248.4 4/6 151/63/68	253.3 4/6 158/69/73	256.2 3/6 165/75/79	257.3 3/6 170/79/83	257.6 2/3 172/82/85
10	246.3 4/6 148/61/67	251.6 4/6 154/65/70	256.2 3/6 160/70/75	258.6 3/6 165/74/78	260.0 3/7 166/76/81	246.8 4/6 149/61/66	251.8 4/6 155/66/71	255.1 3/6 162/72/76	256.6 3/6 167/76/80	257.5 3/6 172/80/84

Figure 1. Tabulated Performance Example

New generation software for aircraft performance data calculation and optimization, that authors have evaluated and worked with, employs the third calculation mode – neural functions. They modify themselves in order to give sought output upon certain input. [5]

Long term experience using polynomial calculations has built knowledge about output as the result of known set of input values. For example: what weight aircraft can have when taking off at 20°C and wind of 10 knots? Knowing the trait of neural functions, aircraft performance data can be calculated and optimized at acceptable (shorter) time.

Understanding the environment in which LAPTOP is used, neural functions are the best solution so far. Time consuming 1st Principle calculation is out of question in short time available for planning the next flight, while results after polynomial calculation have payload trade offs. Therefore neural functions are solely applied in LAPTOP environment.

4.1 Real Life Benefits

In real life today, the main aircraft performance calculation is based on tabulated data. Simple mathematical manipulations are used to reach figures necessary for setting thrust of aircraft powerplants and reference speed values for certain pilot actions. Each combination of thrust setting and meteorological conditions results in distinct value of allowed aircraft weight.

Although all required pilot calculations are simple, they give safe, but not always optimal values. In long term there are two potential loss generators:

- ✈ Unrealized revenue
  unrealized revenue is the result of conservative polynomial calculation used for producing tabulated data regularly. Lower than optimal aircraft weight originates from conservative nature of polynomial calculation.
- ✈ Increased maintenance costs
  increased maintenance costs can not be assessed directly. Annual balance sheet proves that higher than required thrust settings result in aircraft engine deterioration. More precise calculation of reference temperature for thrust setting results in accurate thrust value for given meteorological conditions thus eliminating excessive wear of engines.

4.2 Real Life Example

Let us present three distinct advantages of LAPTOP performance calculation compared to manual calculation.

Assume that aircraft is taking off from a runway 02W at generic airport with known set of obstacles along the take off path. Runway is wet, and atmospheric pressure is lower than standard value of 1013.25 hPa. Outside air temperature is 5°C. Aircraft is using anti ice system, while air conditioning system is set OFF for take off. There is wind of 10 kts (1kt≈0.514 m/s) blowing from 45°.

Basic tabulated performance is computed for dry runway, standard meteorological conditions (air pressure of 1013.25 hPa, defined set of outside temperature values and a set of discrete wind values blowing down the runway) and standard aircraft configuration (Anti Ice System and Air Conditioning System not engaged). (Figure 1.)

58	152/53/57	157/59/62	162/64/68	165/67/71	168/70/73	153/55/58	158/61/64	160/64/67	158/64/67	156/64/67
59	206.5 4/6 152/53/57	210.5 4/6 157/58/62	213.1 3/3 162/64/67	214.3 3/3 165/67/70	215.3 3/3 168/70/73	206.1 4/6 153/55/58	208.1 3/4 158/61/64	208.4 2/3 159/64/67	208.4 2/3 157/64/67	208.4 2/3 155/64/67
	INFLUENCE OF RUNWAY CONDITION									
WET	-3.4 -3 -12/ -3/ -3 (159) -4.2 -3 -12/ 0/ 0	-3.1 -2 -12/ -4/ -4 (159) -3.9 -3 -12/ 0/ 0	-2.6 -2 -11/ -3/ -3 (159) -5.5 -4 -11/ 0/ 0	-2.2 -2 -11/ -2/ -2 (159) -5.0 -3 -10/ 0/ 0	-1.8 -1 -10/ -2/ -2 (159) -4.4 -3 -10/ 0/ 0	-3.1 -2 -13/ -4/ -4 (159) -5.5 -4 -12/ 0/ 0	-2.8 -2 -12/ -3/ -3 (159) -6.6 -4 -11/ 0/ 0	-2.1 -2 -10/ -3/ -3 (159) -6.6 -4 -9/ 0/ 0	-1.0 -1 -7/ -2/ -2 (159) -1.0 -1 -7/ 0/ 0	-0.1 -1 -5/ 0/ 0 (159) -0.1 -1 -5/ 0/ 0
DQNH HPA	INFLUENCE OF DELTA PRESSURE									
-10	-2.0 -2 0/ 0/ 0 (159) -2.4 -2 0/ 0/ 0	-2.3 -2 0/ 0/ 0 (159) -2.3 -2 0/ 0/ 0	-2.3 -2 0/ 0/ 0 (159) -2.3 -2 0/ 0/ 0	-2.4 -2 0/ -1/ -1 (159) -2.4 -2 0/ 0/ 0	-2.4 -2 0/ -1/ -1 (159) -2.4 -2 0/ 0/ 0	-2.2 -2 0/ 0/ 0 (159) -2.2 -2 0/ 0/ 0	-2.3 -2 0/ 0/ 0 (159) -2.3 -2 0/ 0/ 0	-2.4 -2 0/ -1/ -1 (159) -2.4 -2 0/ 0/ 0	-2.4 -2 0/ -1/ -1 (159) -2.4 -2 0/ 0/ 0	-2.5 -2 0/ -1/ -1 (159) -2.5 -2 0/ 0/ 0
+10	+1.2 0 +1/ +1/ +1 (159) +1.2 0 +1/ +1/ +1	+1.1 0 0/ 0/ 0 (159) +1.1 0 0/ 0/ 0	+1.0 0 0/ +1/ +1 (159) +1.0 0 0/ +1/ +1	0.0 0 0/ +1/ +1 (159) 0.0 0 0/ +1/ +1	0.0 0 +1/ +1/ +1 (159) 0.0 0 +1/ +1/ +1	+1.1 0 0/ 0/ 0 (159) +1.1 0 0/ 0/ 0	+1.1 0 0/ 0/ 0 (159) +1.1 0 0/ 0/ 0	+1.0 0 0/ 0/ 0 (159) +1.0 0 0/ 0/ 0	+0.9 0 0/ 0/ 0 (159) +0.9 0 0/ 0/ 0	+0.9 0 0/ 0/ 0 (159) +0.9 0 0/ 0/ 0
	INFLUENCE OF AIR COND.									
On	-2.6 -2 0/ 0/ 0 (159) -3.1 -2 0/ 0/ 0	-2.7 -2 0/ 0/ 0 (159) -2.7 -2 0/ 0/ 0	-2.9 -2 0/ 0/ 0 (159) -2.9 -2 0/ 0/ 0	-3.1 -2 0/ 0/ 0 (159) -3.1 -2 0/ 0/ 0	-3.2 -2 0/ 0/ 0 (159) -3.2 -2 0/ 0/ 0	-2.8 -2 0/ 0/ 0 (159) -2.8 -2 0/ 0/ 0	-3.2 -2 0/ 0/ 0 (159) -3.2 -2 0/ 0/ 0	-3.9 -2 0/ -1/ -1 (159) -3.9 -2 0/ 0/ 0	-4.0 -2 0/ -1/ -1 (159) -4.0 -2 0/ 0/ 0	-3.6 -2 -2/ -2/ -2 (159) -3.6 -2 -2/ 0/ 0

LABEL FOR INFLUENCE	MTOW(1000 KG) codes Vtmin/VR/V2 (kt)	VMC LIMITATION	Tref (OAT) = 37 C Tmax (OAT) = 55 C	Min acc height 1085 FT Max acc height 1950 FT	Min QNH alt 1119 FT Max QNH alt 1984 FT
DW (1000 KG) DTFLEX DV1-DVR-DV2 (KT) IF VMC CAT C: DW (1000 KG) DTFLEX DV1-DVR-DV2 (KT)	LIMITATION CODES: 1=1st segment 2=2nd segment 3=runway length 4=obstacles 5=tire speed 6=brake energy 7=max weight 8=final take-off 9=VMU			Min V1/VR/V2 = 112/12/16 CHECK VMC LIMITATION Correct. V1/VR/V2 = 0.3 KT/1000 KG	

Figure 2. Tabulated Performance Correction Figures

These baseline values are modified by pilots in order to meet actual status at the moment of calculation (Values in Figure 2.). Each calculation can be considered valid at the time of calculation only. Approximate time for that process is not less than 10 minutes assuming quiet cockpit atmosphere and no distractions. After the initial calculation there is another recalculation check needed. If the calculation case is simpler (closer to baseline conditions with less modifications time can drop to 7 minutes at best).

LAPTOP calculation time for the same input values takes 15 s at maximum. It is very important that this time is for the case with maximum number of adjustments to standard values needed. Any simpler case takes from 10s to 14s. This is the first advantage - shorter calculation time.

Comparing aircraft weight permitted for take off LAPTOP calculation in this example gives 207114,5 kg, while pilots calculation based on tabulated data leads to approximately 201.5 t. Difference of 5614,5 kg is just because of improved calculation mode applied by LAPTOP and its numerical precision. That is second advantage – unrealized revenue.

The third advantage is gained when aircraft is to take off at some weight lower that one permitted by actual meteorological conditions and aircraft status. LAPTOP calculation in given example leads to 1°C higher temperature setting resulting in substantial savings in annual maintenance costs.

5. CONCLUSION

LAPTOP based performance data generating and optimization as the idea is recent achievement in airline industry. It has arisen as a logical step forward in today's aircraft cockpit layouts.

Numerous computers in contemporary cockpits have got another addition in the form of a LAPTOP. Although it is still not integrated with other computers completely, it provides data to be inserted as inputs to them. Quality inputs can not lead to faulty or erroneous outputs.

As the system has been designed by an aircraft manufacturer and tested in a group of different airlines, it is meant to be adapted for commercial flying. That is obvious from the intended and already incorporated characteristics (Figure 3.):

- simple user interface (suited to different computer knowledge levels),
- calculation initialization through runway designator,
- direct meteorological and aircraft condition inputs,
- the selection between maximum payload and flexible take-off modes. [5]

All listed characteristics should lead to easier and more efficient usage and results.

User interface should bring more prompt reaction to constantly changing operational situation at any large airport (i.e. switching from one runway to another, additional cargo or less passengers due to lost flight connection, etc.). Actual meteorological and aircraft condition data usage often allows extra weight loading, hence increasing commercial effects of each flight. The choice between two take-off modes reflects on increased profit (by adding revenue in case of maximum payload take-off or decreasing expenses in the long-term use of flexible take-off).

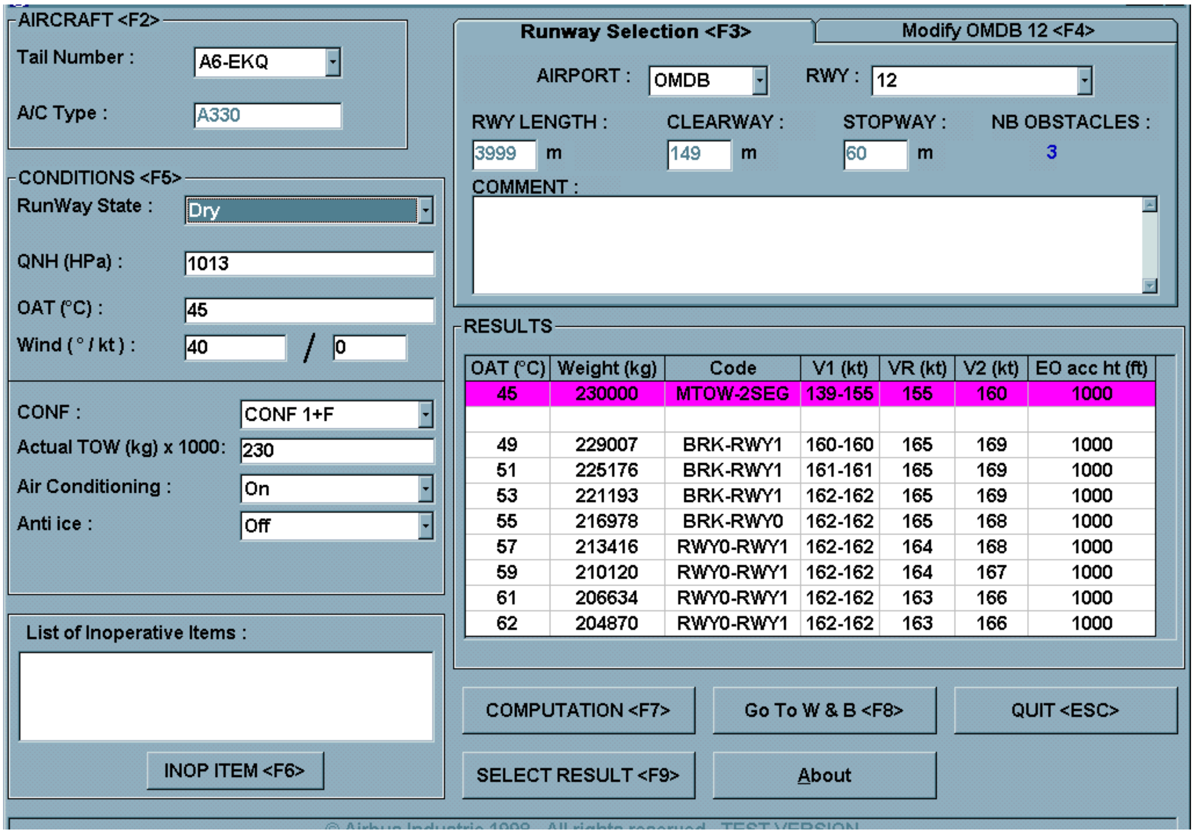

Figure 3. User's Interface to Laptop Based .Performance Data Calculation Module

The system presented in the article is not unique in airline industry today. Some airlines have been using other systems for a while. Although systems do not correspond to each other completely, all users agree – computer performance data calculation in cockpits is quality step forward in airline industry.

6. REFERENCES

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