Title slide

Who are we?

Dstl Support to Operations

- Provides **embedded** Science and Technology (S&T) and **analytical support** in UK headquarters at home and on operations.
- Manages the **reachback facility**, allowing deployed / operational headquarters and planners to access fast turnaround S&T advice from Dstl, 24/7.

[dstl] 26 July 2015

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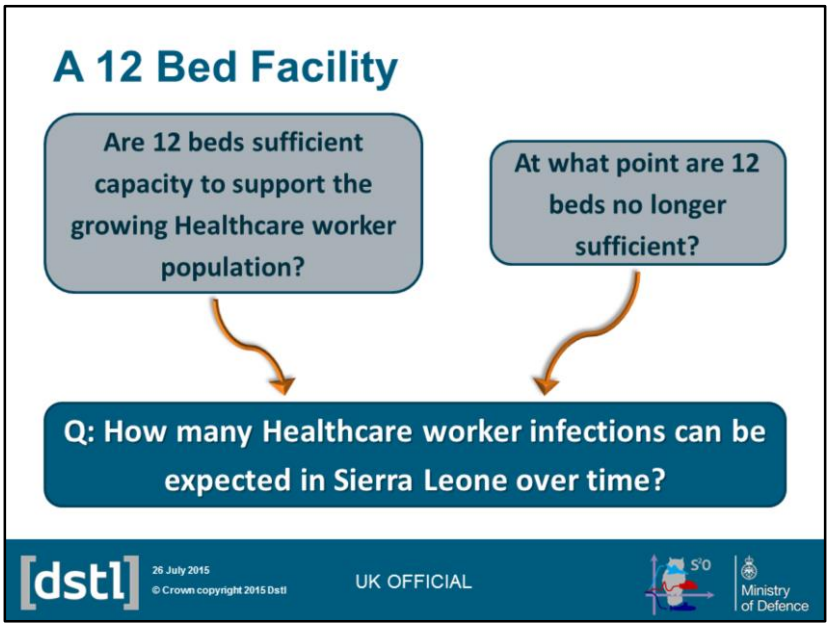
About the group.

This presentation focusses on the analytical bed planning side of Dstl's involvement. It does not cover the work done by OGDs (Save the Children, Medicins Sans Frontieres) or the lab work / staff provided by Dstl.

Basic outline of events leading up to Dstl's involvement.

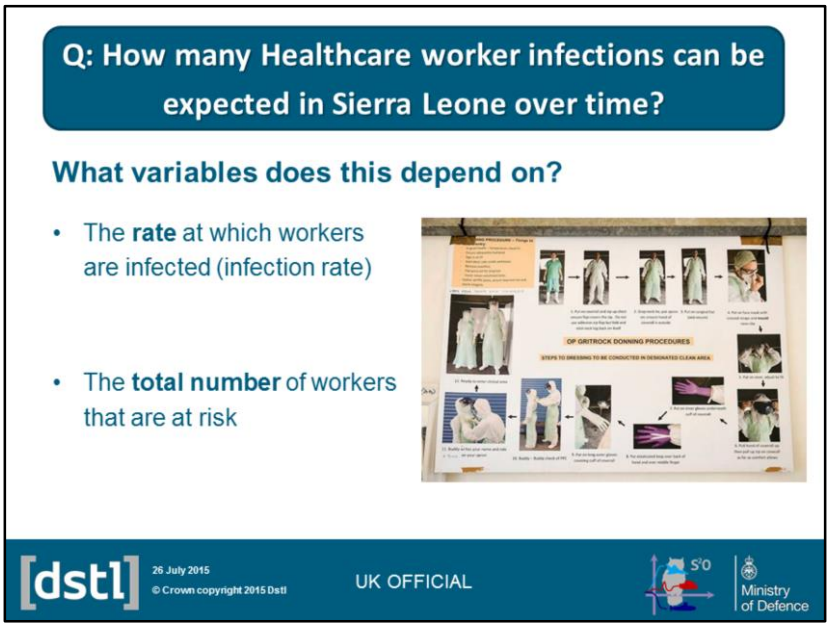
1. In March 2014, a rapidly evolving outbreak of Ebola haemorrhagic fever started in Guinea. The outbreak subsequently spread to Liberia, Sierra Leone, Nigeria and Senegal.
2. On 8 Aug, WHO declared the Ebola outbreak in West Africa a Public Health Emergency of International Concern (PHEIC). UK effort to provide aid to Sierra Leone is started.
3. Different levels of treatment are likely to be provided to different groups, with Healthcare Workers (HCW) who put themselves at risk of Ebola the most critical group.
4. Therefore the UK has been asked to design build and operate a treatment centre open only to HCW. OP GRITROCK is started.
5. The capacity of this facility has initially been set at 12 beds (8 treatment and 4 isolation), based on what could easily be delivered in the timescales. Given the increased potential demand for the facility as more and more HCW enter the country, this raises the obvious question…



Questions asked by Ops Directorate, who inform the Gov. planning for the treatment centre.

Are 12 beds sufficient, and at what point are they no longer sufficient (decision points)?

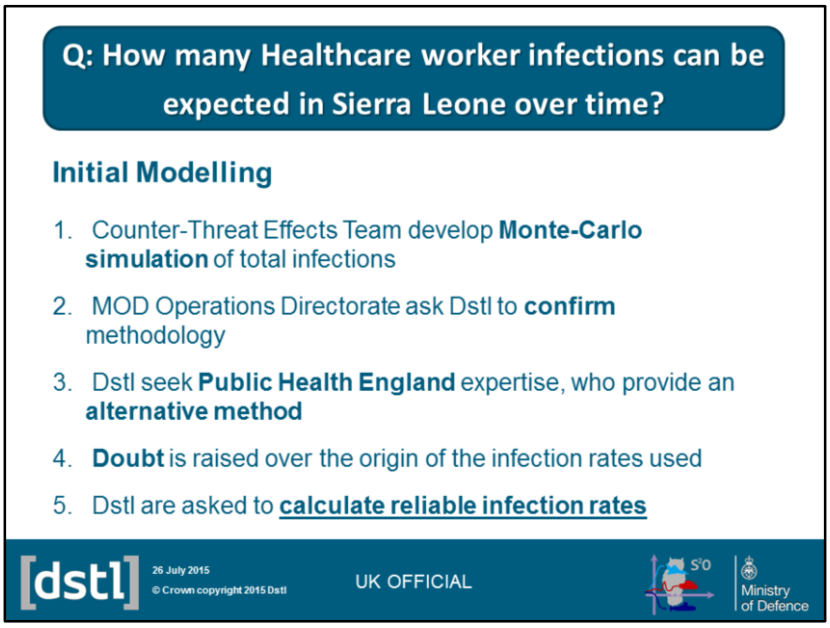
Both rely on the more fundamental question: how many HCW infections are expected in Sierra Leone over time?



Slide to put the key challenges into context.

What are the key variables affecting this?

The infection rate and PAR are most important. Highlight the fact that at this point in time the only information passed around was assumptions on both. We will come back to this later.

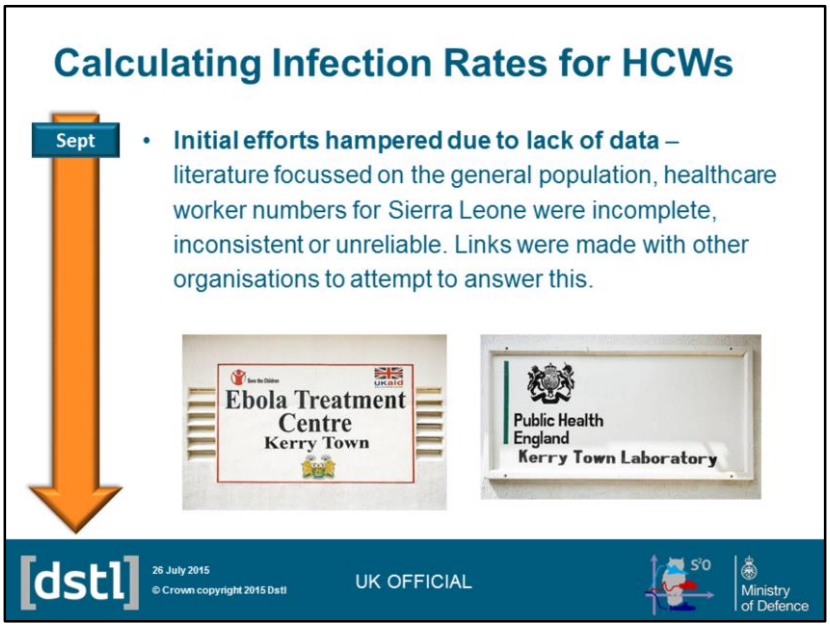


This is where we were initially involved.

As part of the Operations Directorate, the Counter-Threat Effects Team made the first attempts to answer this question and Dstl (through S2O) were asked to confirm (or deny) the validity of the answers.

To do this, we originally asked PHE to help as they have more expertise in the area and are more likely to have the relevant knowledge. During these discussions we became curious as to why the OpsDir had given us percentages of population that would be infected, and it turned out that these were (on a very basic level) simply educated guesses from the surgeon general.

The need for formal clarification of the infection rate became apparent, and Dstl were tasked to do this.



Mid September.

Have HCW infection rates been studied? (No)

Open-source literature focuses on spread in the **population**, not HCWs

Done in terms of parameters other than "infection rate" (e.g. R_0)

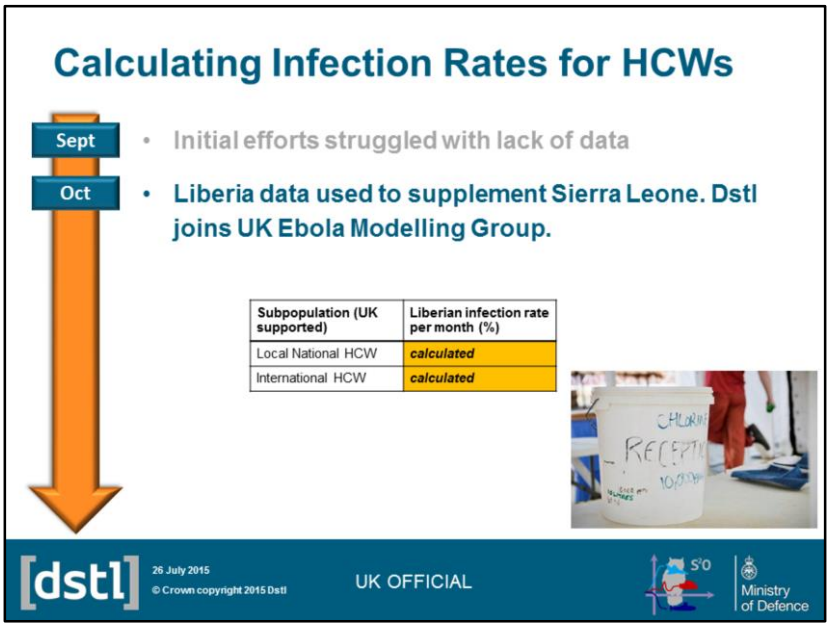
Do we have enough to calculate them? (No)

Infection rate needs **total infected, people at risk,** and **time at risk.**

Real Sierra Leone data was initially **unreliable** or scarce.

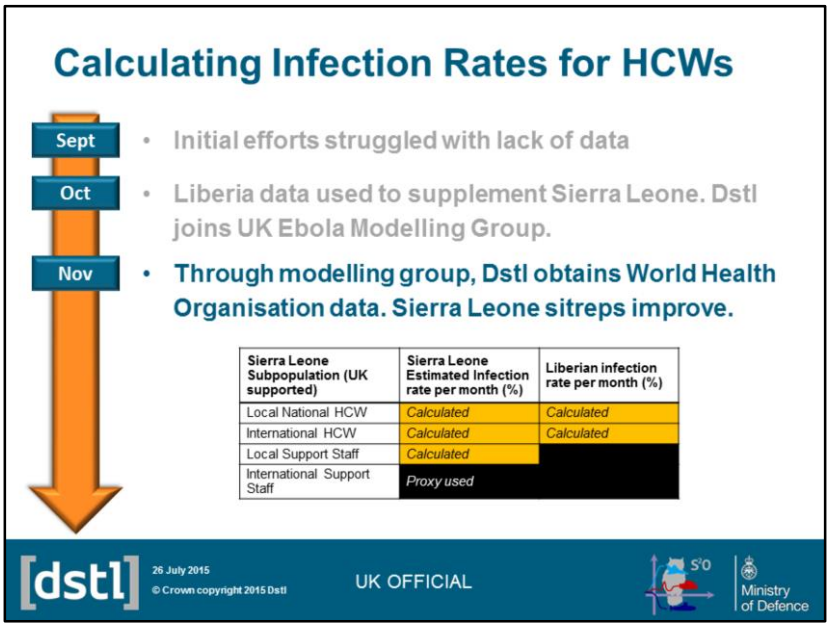
Recent reporting was reconsidered to look for the most up-to-date figures.

HCW specific numbers for **Sierra Leone** were **incomplete**, **inconsistent** or **unreliable**.



October – first results. Significant uncertainty, but already seeing that the doubt in the rates was justified.

1. International workers have **different rates** to local nationals, treat each separately (differing levels of PPE [initially], training, etc.)
2. Scale the number of HCWs in role in Sierra Leone to estimate numbers in Liberia
3. Assume HCWs have been there for **6 months** of the crisis
4. Use infected numbers from Liberia to **calculate individual infection rates** and generate a (weighted) average infection rate for **Local Healthcare Workers**
5. Use **Médecins Sans Frontières reporting** to generate an average infection rate for **International Healthcare Workers**



WHO Sierra Leone data received: Nov 2014

SL Sitreps are collated by the US (Caitlin Rivers)

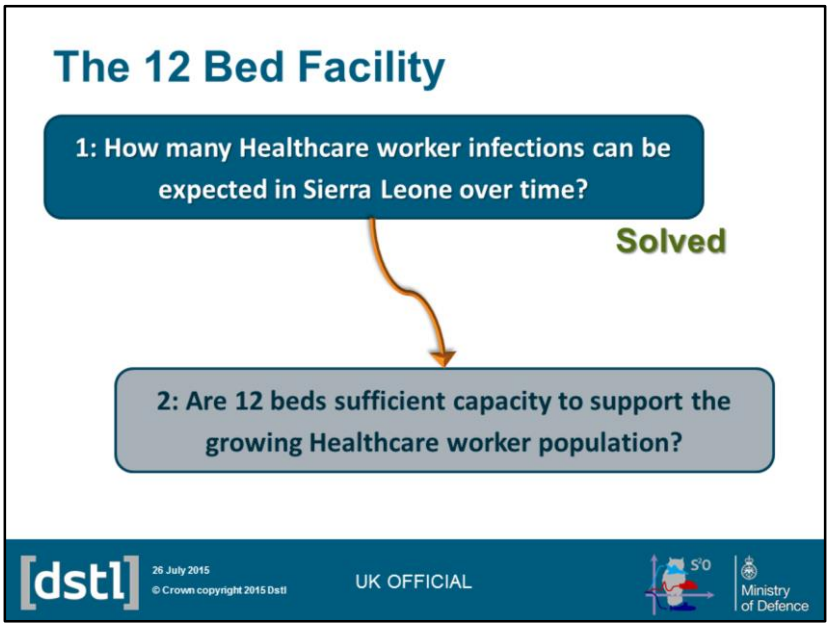
Green – Data source can be justified as reliable (consistent updates and can be cross referenced with other data sources to confirm numbers) and as current as possible. The confirmed cases of EVD haves time stamps.

Amber – Data source is questionable (updates are inconsistent and cross referencing with other data sources shows discrepancies), or second-hand.

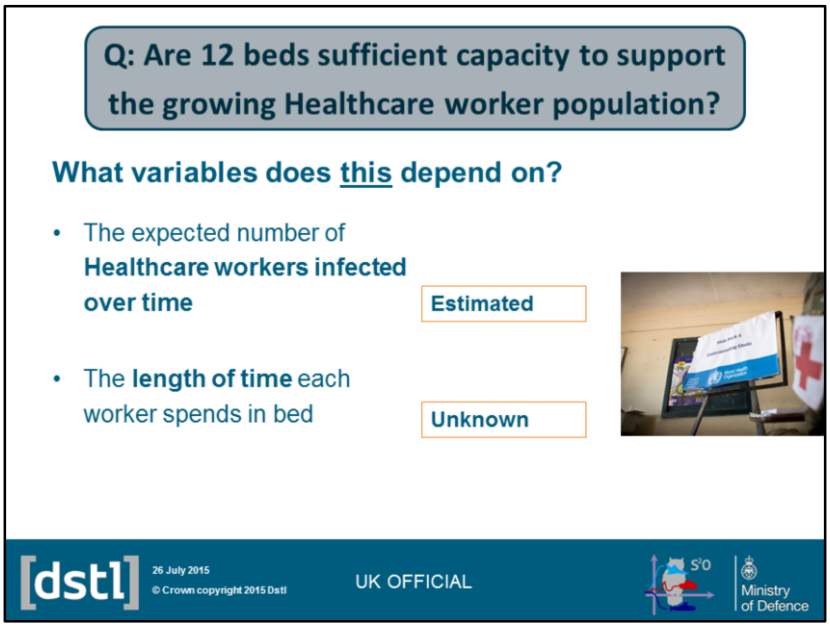
Red – Source is spurious, out-of-date or unreliable.

Black – Data currently doesn't exist or is unavailable. Weekly/monthly breakdowns of population are available, rather than cumulative totals since outbreak.

High uncertainty still, but good bounds on the values. Can use these going forwards.

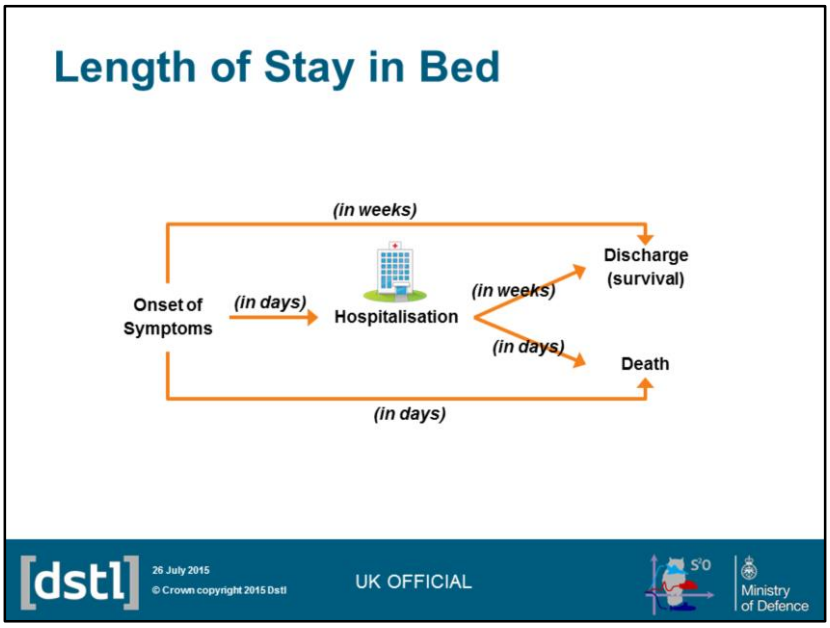


Now we've answered the base question, attempts can be made to answer the relevant original questions.



Slide to highlight key challenges.

Dstl were (again) not the ones originally modelling the bed occupancy, but we took over from PJHQ.

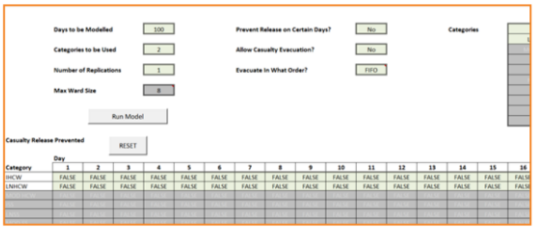


Used various different sources to attempt to fill this diagram in. Even though only two of the parameters are of relevance, needed to get all of them to check for (a) consistency, and (b) allow us to vary e.g. time **before** presentation, which may be lower for HCWs.

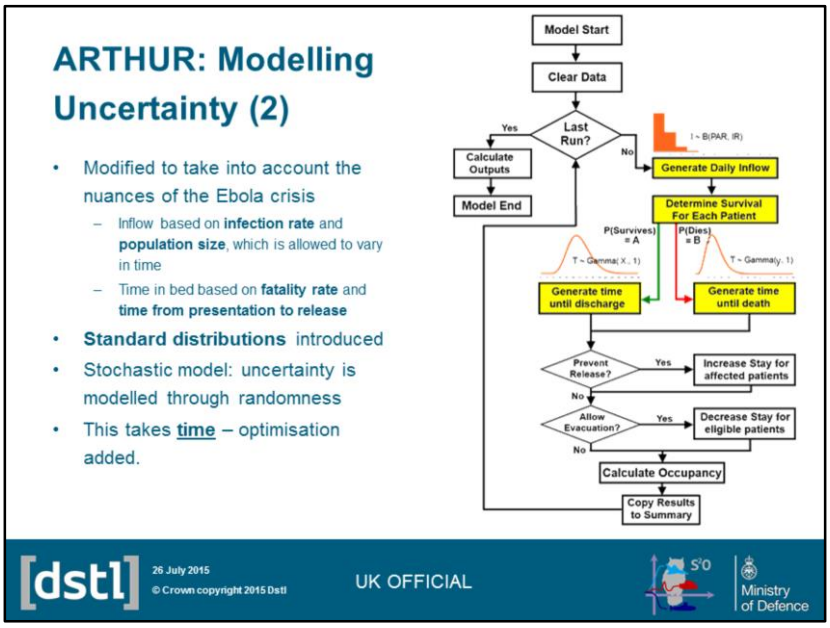
Note hospitalisation-discharge bigger than hosp-death, and onset-hosp is smaller for HCWs.

ARTHUR: Modelling Uncertainty (1)

- The **Analysis of Requirements Tool for Hospital Utilisation and Resources**
- A **stochastic** model
- Models **bed occupancy** for different categories of patient.
- Used to assist with **medical planning** for deployed medical facilities in operations such as **Afghanistan**.



Talk about original ARTHUR tool, and its purpose. If time, highlight potential flaws.



How do we use this to answer the original question? (How many HCW infections in SL per week)

We took the existing ARTHUR model, which already did some of what we wanted, and looked at what features needed to be added that were specific to this question.

Firstly the number of patients presenting was previously done from specified probabilities - we now wanted to specify this in terms of infection rate and the population at risk, which could potentially vary as new HCWs arrive or old HCWs return.

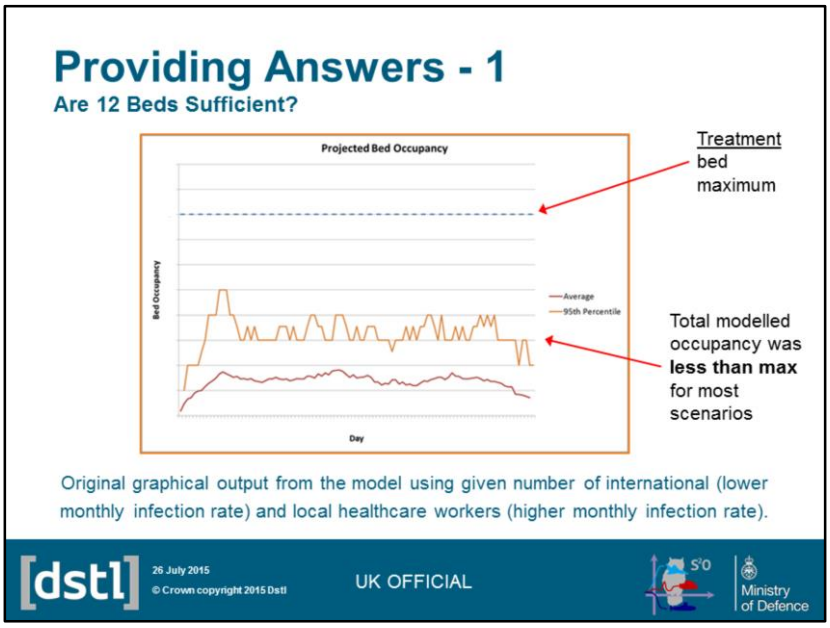
Secondly, the length of time each patient spends in bed, again previously specified by probabilities, is now a function of survival (which depends on the fatality rate) and the average time it takes to care for them, so it made sense to use these as inputs instead.

We found we could do both of these by taking the inputs we wanted to use (the words in bold) and turning them into the inputs that ARTHUR already took (cumulative probabilities) through standard distributions

And it didn't take long to realise that the limits ARTHUR imposed (max. 40 patients in per day, max. 10 day stay, max. 50 days modelled) could be exceeded for some input values, so we increased these

We then had a stochastic model that gave us a predicted number of beds occupied and ranges around these (e.g. 95th percentile)

But this takes time to complete for every set of inputs. This was why some of the later questions were so hard to answer – it becomes impossible to look at continuous variations in the input data and so it's not possible to look at the whole picture.

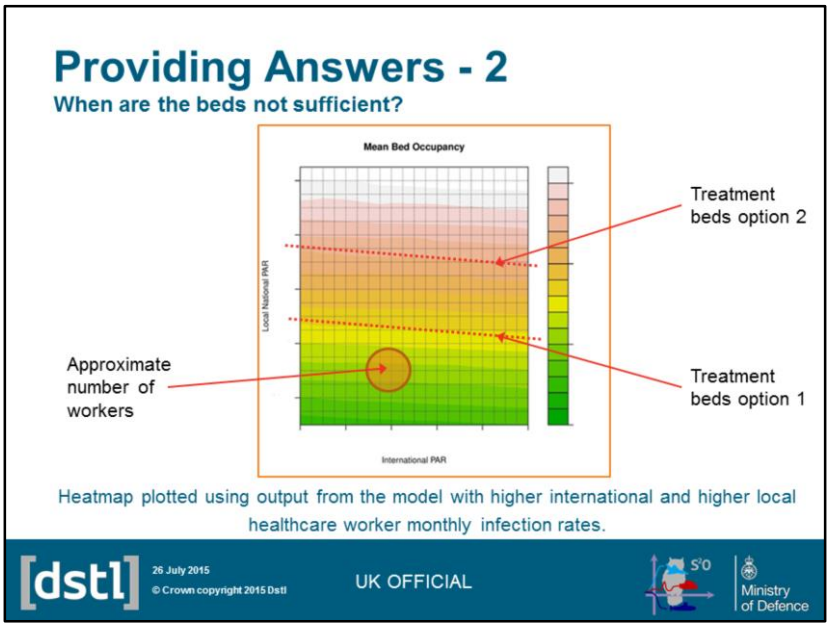


Axes removed to lower classification

Now that we had a model and values for each of the inputs, we could begin looking at the predicted occupancy and provide some responses. While the capacity had been set at 12 (8+4) beds, the Ops Directorate were also considering the option of 16 (12+4) beds. However, as you can see from the example output shown, there were very few scenarios where the modelled daily occupancy rose above 8 at the 95th percentile. The graph shown here was generated using the lower infection rates, a Y% CFR and X days in bed.

We found that even using the higher infection rates (X%, Y%) and nearly double the number of local healthcare workers, the modelled occupancy stayed below A or B. This was possibly the worst case we saw.

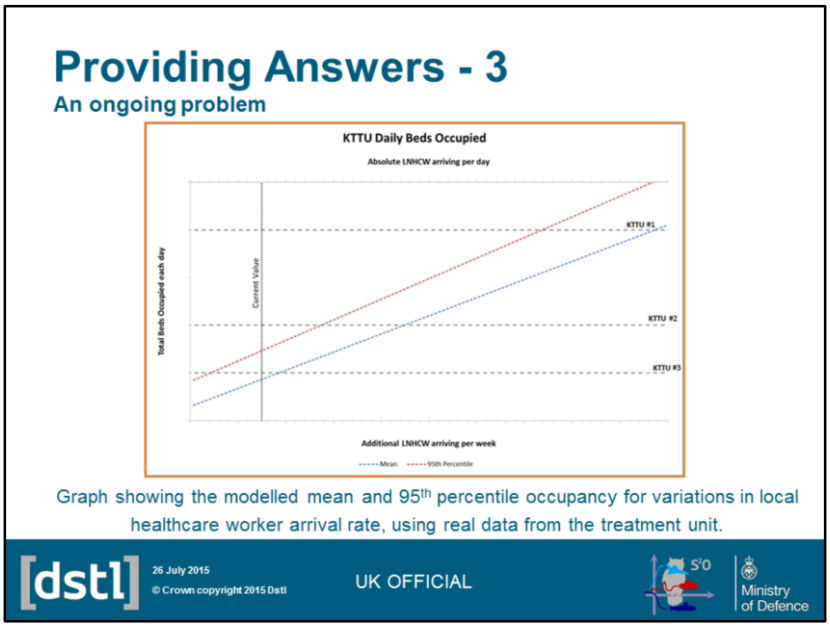
Because of the upper and lower “choices” for infection rates and some uncertainty surrounding the exact number of healthcare workers in country (Sierra Leone), at the beginning we were running 4 or 5 scenarios on a regular basis as new numbers came in and the question was asked again. So to cope with this and try to handle some of the uncertainty we let the model run hundreds of scenarios on its own.



Axes removed to lower classification and estimated circle made much larger

This allowed us to plot a heatmap (using R) where two of the parameters are varied. Originally we had the greatest uncertainty around local PAR and local IR so the first heatmap plotted these. This was interesting as it highlighted two points where the model hadn't been run for long enough, so for the next heatmap (which is the one shown – at this point we were also tasked to consider a 16+4 bed facility) we ran the model for twice as many replications (100).

The graph shown is the mean bed occupancy – we also produced similar maps for the 95th percentile – and it still clearly shows that the 8 treatment beds are sufficient for the estimates of HCW numbers we were being given. However, the advantage of plotting the results this way was that it allowed us to also calculate when the given number of beds would **not** be sufficient – the "breaking point". By fixing the number of international workers at A VALUE, for example, (as the Ops Directorate could be more certain of this number) we knew that 8 beds could support up to X local nationals at the mean occupancy and between A-B at the 95th percentile with the higher infection rates. Other bed sizes and infection rates were also tried and the results of those passed on to the Ops Directorate.



Axes removed to lower classification

The challenges in Sierra Leone are ongoing, and we now have about 3 months of real Kerrytown treatment unit patient data. This has allowed us to compare our model's output with the actual occupancy to both gain confidence that the model is accurate, and narrow down some of the parameters that have uncertainty associated with them. This graph is some of the more recent output from our model, aiming to inform the setting of **decision points** – i.e. when the facility size will be increased or decreased. Here, due to the unknown population sizes but data on arrivals, we've moved to using absolute arrival rates in place of infection rates. This particular version made its way all the way up to the Cabinet Office Briefing Rooms, where it informed a recent decision to downsize the facility.

More analysis is now underway, taking the triage beds into account, to inform a future decision on whether to downsize even further to either an 8 (4+4) bed facility, or even just a 4 bed holding unit.

Impact

- Analysis has informed decisions on **medical rules of eligibility**.
- This informed the **increase** in the number of beds and widening of the rules.
- Further output stopped decision makers from moving to more, unnecessary beds.
- Recent analysis has informed a decision to move to a **smaller ward size**.

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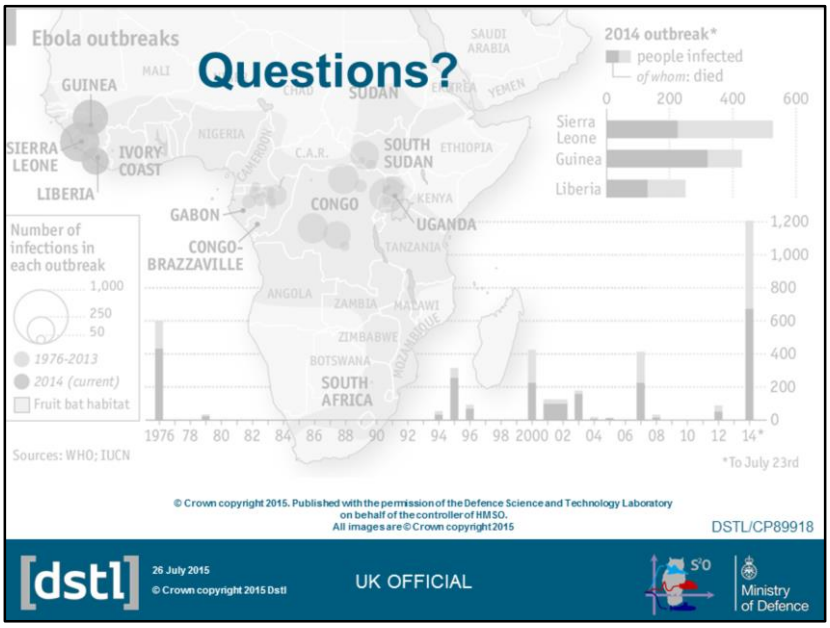
CO 22 Field Hospital, Lt Col Alison McCourt: There were too many beds for a while, and staffing/maintaining them was a huge burden.


Ebola outbreaks
Questions?
2014 outbreak*
people infected
of whom: died
0 200 400 600
Sierra Leone
Guinea
Liberia
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
MALI
NIGERIA
CAMEROON
C.A.R.
SOUTH SUDAN
SUDAN
ETHIOPIA
ERITREA
YEMEN
SAUDI ARABIA
GABON
CONGO-BRAZZAVILLE
CONGO
KENYA
UGANDA
TANZANIA
ANGOLA
ZAMBIA
MALAWI
MOZAMBIQUE
ZIMBABWE
BOTSWANA
SOUTH AFRICA
Number of infections in each outbreak
1,000
250
50
1976-2013
2014 (current)
Fruit bat habitat
1,200
1,000
800
600
400
200
0
1976 78 80 82 84 86 88 90 92 94 96 98 2000 02 04 06 08 10 12 14*
Sources: WHO; IUCN
*To July 23rd
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